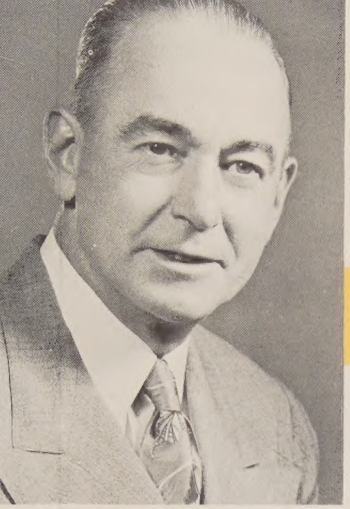
GENERAL MOTORS

Engineering JOURNAL

Volume 1 January-February 1954 Number 4



On Achieving Success in Industry

AMONG the many forces which direct the course of our lives and so influence our conduct, perhaps the most impelling is the desire to be constructive, to attain, to leave our mark. Certainly, we are all hopeful, at least at times, that we will leave the world and the people we meet better for our having been here and having met them.

Living can be defined as the sum total of all the things we do and say. In our efforts toward successful living, it seems imperative that we recognize the power of attitude—for it is our attitude, right or wrong, which channels our actions and thereby determines our ultimate accomplishment.

This applies to everyone but particularly to students, who in their formative years are establishing a basic pattern for living. In their pursuit of this objective there is a need for the development of right attitude toward (1) work and (2) people.

An individual with the right attitude toward work will see it not as economic drudgery necessary to making a living but rather as an opportunity to develop and express latent talents, and in so doing, come to learn that the height of his attainment is measured directly by the elastic limit of his abilities. With such an attitude he will never be satisfied with the comfort and complacence of mediocrity but, driven by this force, he can be satisfied only when he has given his best.

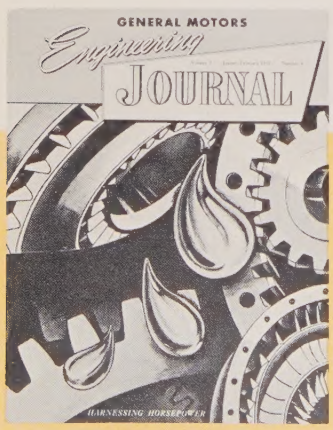
With a good attitude toward people he will find them all-important to his success. None of us can do his best without the help and assistance of others. From this discovery, we come to understand the fundamental value of cooperation and joint effort—teamwork as we call it.

This dependence on others continues no matter what the degree of our success. In fact, it might be said that the greater our success the more we depend on others.

This interdependence among people is essential to success in every field of endeavor. It is particularly necessary in industry, where the success of the enterprise as a whole is so assuredly the result of the combination of individual efforts. There is not one of us, regardless of our field of work, who has not come to understand the need for cooperation and friendly understanding even in that smallest segment of social life, namely the home.

The great advances that have been made during the last century in the development of material things have contributed importantly to our standard of living. These valuable contributions could not have been made without engineers and engineering students with the right attitudes toward work and toward people. To those who follow in the footsteps of the pioneers falls the challenging responsibility of continuing that progress.

J. J. Cronin,
Vice President in Charge of Manufacturing Staff



THE COVER

In the third of a series on the development of transportation, Artist John Tabb has chosen transmissions as his subject. The cover design uses parts of several transmissions to portray today's production emphasis on the Dynaflow, Hydra-Matic, Powerglide, and Synchromesh transmissions. For many years transmission design remained nearly static, but since the introduction by General Motors of successful automatic transmissions and the enthusiastic public acceptance of such transmissions, this phase of automotive engineering has become extremely active. The fact that there are three schools of thought among General Motors engineers is ample evidence that there is no unanimity of opinion as to how best to do the job even though there may be general agreement on what the ideal transmission ought to do.

CONTENTS

TECHNICAL COMMENTARIES

Page

Major Cooling Problems Encountered in Today's Automobiles, *by Harold A. Reynolds, Harrison Radiator Division* 2

The Material-Utilization Activity in a Manufacturing Plant, *by Robert F. Smith, Delco Appliance Division* 37

GM LABORATORIES AT WORK

A Survey of Balancing Machine Developments in the Research Laboratories Division, *by Thomas C. Van Degrift, Research Laboratories Division* . . 7

The Effect of Combustion-Chamber Shape on Smoothness of Power, *by Harvey L. Mantey, Cadillac Motor Car Division* 14

Diesel Engine Improvements through Experimentation with Fuel Injection and Combustion Chamber Relationships, *by Herbert H. Black, Diesel Equipment Division* 32

ENGINEERING PROGRESS AND FACILITIES

A Design Study: Planning Maximum Storage and Shipping Ease and Economy into Commercial Vehicle Bodies, *by W. Walter Berger, Chevrolet Motor Division* 20

The Buick Air Power Carburetor, *by Adolph F. Braun, Buick Motor Division* 26

ENGINEERING NEWS

Notes About Inventions and Inventors, *by Charles T. Cross, Patent Section, Central Office Staff* 40

Recent Speaking Engagements Filled by GM Engineers 48

OTHER FEATURES

A Message to Engineering Educators, *from Kenneth A. Meade, Secretary, Advisory Board* 31

A Typical Problem in Automotive Design: Determining Exhaust Valve Cone Angle for a Ball in the Dynaflow Transmission, *by Clifford C. Wrigley, General Motors Engineering Staff* 45

The Solution to the Problem: Determine the Most Economical Strip Length for a Bracket, *by Charles M. Rubly, Chevrolet Motor Division* . 46

Contributors to January-February 1954 issue of GENERAL MOTORS ENGINEERING JOURNAL 50

GENERAL MOTORS Engineering JOURNAL

Vol. 1 January-February 1954 No. 4

Published with the help of General Motors engineers everywhere.

The GENERAL MOTORS ENGINEERING JOURNAL is published every other month by the Educational Relations Section of the Department of Public Relations, General Motors Corporation, and is intended primarily as a medium for presenting to the field of engineering education the results of General Motors research and engineering developments both in the product and production fields.

ADVISORY BOARD

C. A. CHAYNE, Vice President in Charge of Engineering Staff

J. J. CRONIN, Vice President in Charge of Manufacturing Staff

PAUL GARRETT, Vice President in Charge of Public Relations Staff

J. F. GORDON, Vice President and Group Executive

C. L. McCUEN, Vice President and General Manager, Research Laboratories Division

C. R. OSBORN, Vice President and Group Executive

S. E. SKINNER, Vice President and Group Executive

Secretary: K. A. MEADE, Director, Educational Relations Section

STAFF

ARVID F. JOUPPI, Editor

JOHN BRYANT, Associate Editor — ERNEST W. SCANES, Art Director

ANTON BEARD and PATRICIA CLARK, Editorial Assistants

D. O. BRYSON, Production Manager

Address: GENERAL MOTORS ENGINEERING JOURNAL, General Motors Building, 3044 W. Grand Blvd., Detroit 2, Mich.

Copyright 1954 by General Motors Corporation. All rights reserved under the International and Pan-American Copyright Conventions. Requests for permission to reproduce any part or parts of this publication may be directed to the Editor.

Major Cooling Problems Encountered in Today's Automobiles

By HAROLD A. REYNOLDS
Harrison Radiator Division

Today's new requirements always cut into yesterday's engineering gains

Dissipation of the heat of the engine has long been an area of fruitful investigation by automotive engineers. Committed from its earliest days to water cooling for its internal-combustion engine, the automotive industry has seen constantly increasing demands placed on the cooling system, the radiator in particular. During the past 15 years, the problem has been especially complex because gains in other areas of the automobile—even of styling—have depended much on gains in cooling capacity and efficiency. Requirements of military vehicles pointed out the need for specialized solutions, some of them applicable to automobiles and trucks. During many of these years, the knowledge and skill of engineers in meeting a shortage of critical materials, such as copper, have proved especially of value in contributing to automotive progress.

Prior to World War II, the supply of copper, brass, tin, lead, and zinc, the major materials used in the fabrication of cooling system radiators, was generally adequate to meet demand. With the beginning of the armament program, following the outbreak of the war, it quickly became apparent that the reserves of these metals would soon be depleted due to the tremendous civilian requirements existing at the time and because of their importance to arms production. Following the depletion of reserves, it also became apparent that the use of the available supply would have to be vigorously controlled in order to make certain that the armament program would not suffer.

Some of the major sources of these metals, particularly tin, fell into the hands of the enemy and further reduced available supply to the United States and its allies. In addition to the requirements of the armament program, certain essential civilian requirements which were necessary to promote and carry out the defense program also required the use of these metals.

For these reasons, the Federal Government developed a program of allocation and end-use controls as well as a stock-piling program. It became clear that many of the less essential civilian requirements for these metals could not be met. In order to relieve these shortages of supply, new sources were sought with some degree of success while, at the same time, industry was requested and encouraged to develop and use substitutes wherever possible.

The Post-War Picture

At the conclusion of hostilities, the huge pent-up demand for consumer goods outweighed the supply of these metals. At the same time, the Federal Government felt it necessary to continue to stock pile in view of the far-from-settled world situation. Thus, even after World War II, supply did not meet demand and it was necessary for industry to continue its search for practical substitutes.

Realizing that certain historical requirements for these metals could never be satisfactorily overcome by the use of substitutes—at least with the technical knowledge then available—producers of these metals continued their development of new sources, many outside the United States.

For example, huge investments for the production of copper from overseas sources were made in foreign countries by some of the major producers, since it was evident that copper from domestic sources would not meet total demand for some time to come. It was necessary to meet this demand because no satisfactory substitute had been found for certain uses of copper, particularly as a heat-transfer medium.

Because of the necessity of producing copper thousands of miles away and transporting it to the United States, costs increased considerably. Domestic prices also displayed important increases because of a rising cost of production.

In view of the relatively high efficiency of current core surfaces, developed through years of experimentation with various designs, materials, metal thicknesses, and manufacturing processes, it was clear that other factors contributing to the overall cooling requirements would have to be explored in order to hold copper usage to a minimum.

As most of the items under consideration were outside the province of the radiator manufacturer, the Harrison Radiator Division's engineers collaborated with the General Motors automobile manufacturing Divisions to analyze all phases of cooling in an effort to improve the overall cooling system efficiency.

Solutions to Engineering Problems

Considerable success was obtained through the use of higher cooling system pressures, reduced engine-heat rejection, improved grilles and fans, greater use of fan shrouds, higher axle ratios, a slightly lower cooling index, and other factors. A combination of all possible gains in one installation would permit a reduction of 25 per cent to 30 per cent in the copper requirements.

However, the evolution of post-war automobile design was quite rapid, particularly in the addition of supplementary equipment and power-driven accessories. In quick succession, automatic transmissions, power steering, power brakes, and finally, air conditioning were made available to new car buyers and their acceptance was so universal that they are now considered optional equipment on most cars.

Unfortunately, all of these requirements either presented a continuing additional demand to be absorbed through the radiator or, because of their size, shape, or location, reduced the cooling performance due to the effect on the under-hood air delivery. Inasmuch as the ambient air is the final medium of heat absorption of so-called water-cooled engines, any reduction in volume or weight of the cooling air is detrimental to the radiator cooling index. A comparison of the pre-war and the 1953 Cadillac (Fig. 1) graphically illustrates the increase in under-hood space utilization due to the installation of supplementary equipment.

To further complicate the cooling problem, the post-war styling trend toward lower hood lines, low positioning of grilles, new engine designs of greatly increased horsepower, and numerous minor refinements all have presented some influence on the cooling demand of present-day automobiles.

Due to traffic congestion on overcrowded highways, especially in the heavily populated areas, cars were forced to idle or creep slowly toward traffic control points, such as bridges and tunnels. This traffic condition introduced another factor in cooling demand that was rather difficult to overcome. Many cars, adequately cooled for full-throttle operation at speeds from 30 mph to 90 mph, would boil in a short time if idled or driven at speeds below 10 mph for an extended period.

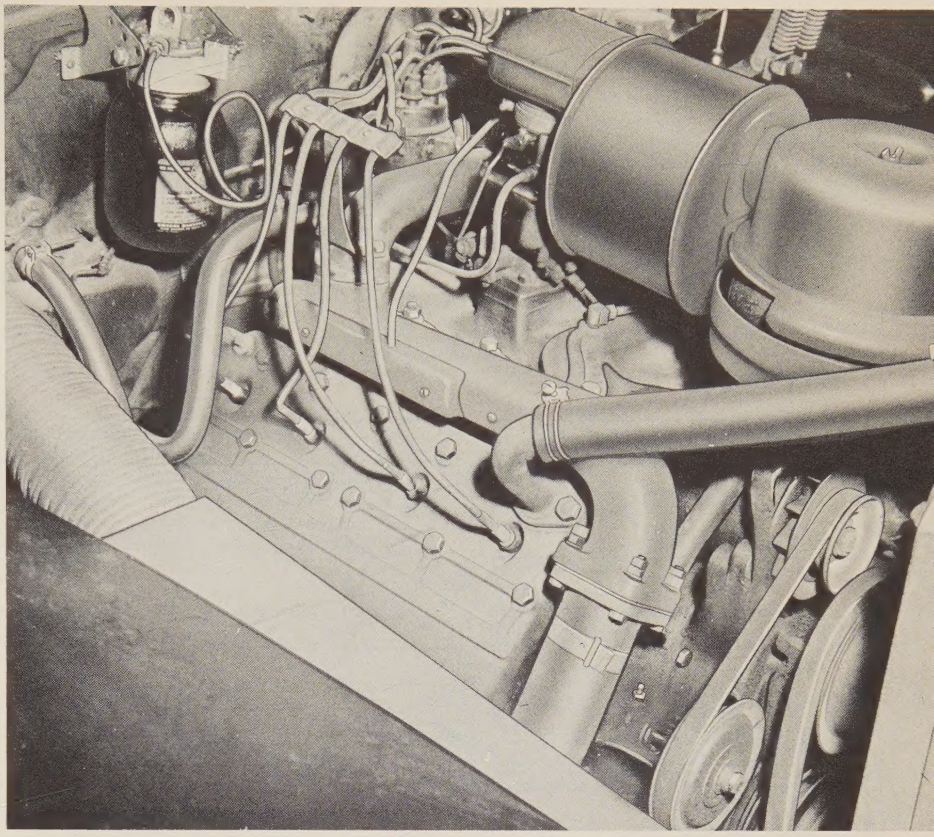
In most instances, additional space was not available for radiators with larger frontal areas. Therefore, it became necessary to investigate every possible means of improving cooling system efficiency.

Pressure Operation

Although pressure caps (Fig. 2) were available and in limited use on several makes of cars as early as 1937, their primary function at that time was to prevent or reduce water loss due to temporary overheating. Overheating tended to occur from extreme power demands or residual heat accumulation after a high-speed run followed by a sudden stopping of the engine.

On most atmospheric systems of this era, efforts to maintain an adequate coolant supply were directed toward either providing excess cooling capacity in the radiator core or an oversize top tank. Such a tank would need to be large enough to compensate for losses resulting from expansion and temporary overheating of the cooling system. Results with this design of radiator were very unsatisfactory. It provided no definite or stable liquid level in the system. Still larger tanks were tried and used by many car makers, but they only increased the total coolant loss when the system overheated. This coolant loss was so annoying to car owners, especially during the season when anti-freeze solutions were required, that a great many users installed reserve tanks to recover their overflow loss.

The first pressure caps were installed primarily to relieve or eliminate this ex-



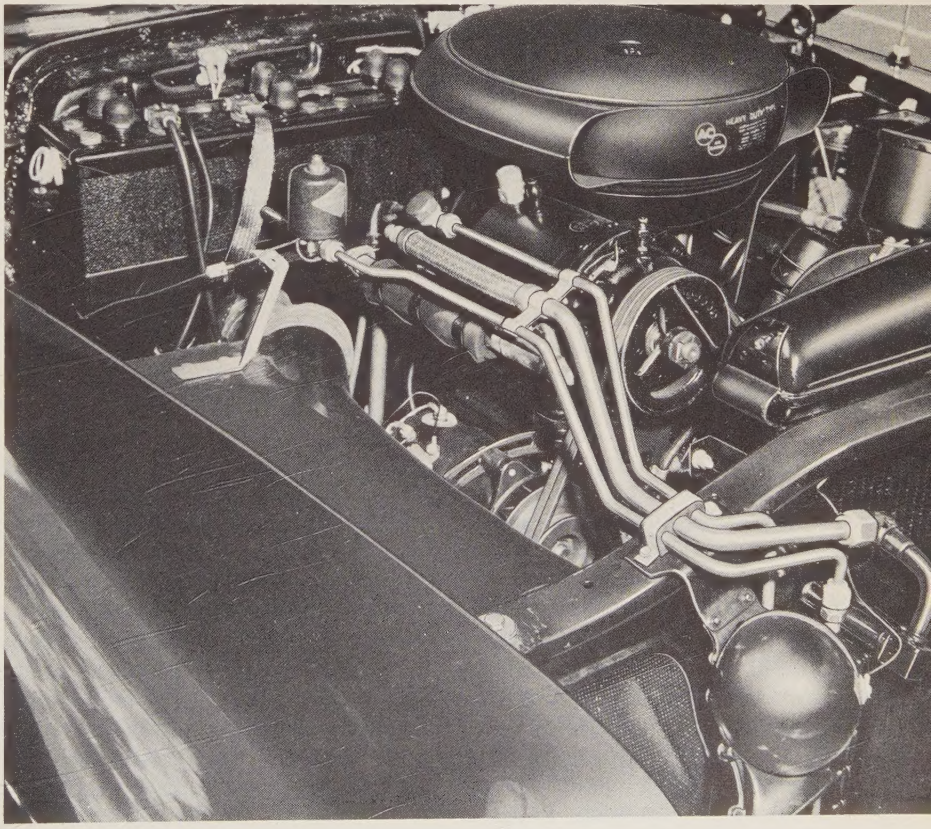


Fig. 1—In making their many gains, other automotive engineers made the cooling engineer's task more complicated. The cooling system had to meet the challenge of restricted under-hood air flow in modern automobiles. For example, compare the pre-war Cadillac's engine compartment (above) with that of a 1953 Cadillac equipped with air conditioning.

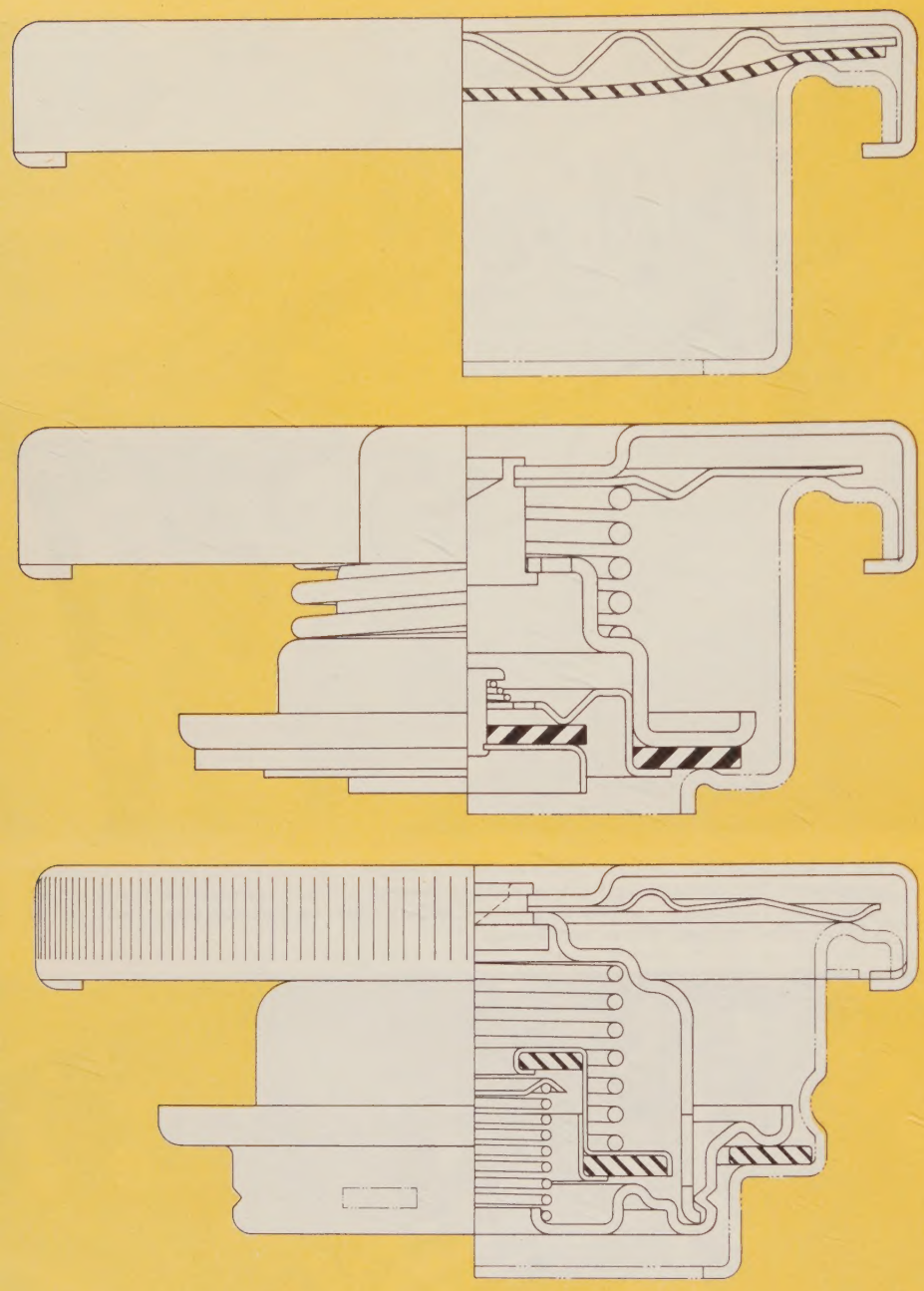


Fig. 2—Radiator caps have undergone three definite stages of development with many smaller improvements in the process. The simple cap (top) was not of the pressure type. The first successful spring-loaded pressure cap is shown in the center. At the bottom is today's spring-loaded cap. The spring is engineered to the desired pressure against the coolant.

cessive water loss. Although the initial designs were somewhat erratic in their operation and ability to hold pressure, the overall results were encouraging.

It soon became evident that the then-current radiator tank designs (Fig. 3) were not capable of retaining liquids, even at the low pressures (4 lb), without excessive deflection which caused extensive ruptures at the tank-to-core soldered joint. To overcome this defect, radiator tanks and structures were re-designed to resist the alternate positive and negative pressure applications encountered in normal operation.

Top tanks were reduced in size so that the capacity provided was only a minimum reserve over the expansion of the total coolant system and tank overhang was distributed equally over the front and rear core faces. Excellent results were obtained with these designs, especially as a cure for water loss evils. However, little advantage was taken, until later, of the potential provided by higher pressure operation to increase the cooling index or to reduce core capacity.

Car-cooling requirements were based on the atmospheric cooling index and the additional capacity provided by the pressure was utilized only as a reserve and water-loss protection. During the war, however, the cooling difficulties presented in the design of military tanks, armored cars, and various other mobile equipment forced cooling engineers to consider high-pressure operation of the cooling system. Air intakes were restricted due to the construction requirements of bullet-proof grilles; space was at a premium and the vehicles were required to be operable in tropic desert areas. The increased differential resulting from the higher boiling temperature provided the only satisfactory means of operation.

Cooling system capacity is increased in direct proportion to the increase in boiling temperature of the coolant—approximately three degrees per lb of pressure. For example:

- A 4 lb cap (222° F boil) provides 10 per cent increase.
- A 7 lb cap (230° F boil) provides 18 per cent increase.
- A 13 lb cap (243° F boil) provides 31 per cent increase.

Such cooling percentage increases permit a reduction in the frontal area of these amounts for the same cooling demand or maintaining the same cooling index with an increased demand. However, before increased-pressure and higher-temperature operation could be adopted, some major changes in the radiator design and fabrication processes were found necessary.

In addition to balancing the tanks on the core which was adequate for the low-pressure operation, the tank contour was changed to incorporate curved surfaces which minimized wall deflection and offered better resistance to the effect of the higher internal pressure. Pump seals were re-designed to prevent leakage under pressure, material specifications of coolant hoses were revised to accommodate the higher pressure and temperatures, cylinder-head gaskets were improved to prevent excessive leakage, and minor changes were incorporated to relieve under-hood temperatures and their effect on pre-vaporization of fuel in the gasoline pump.

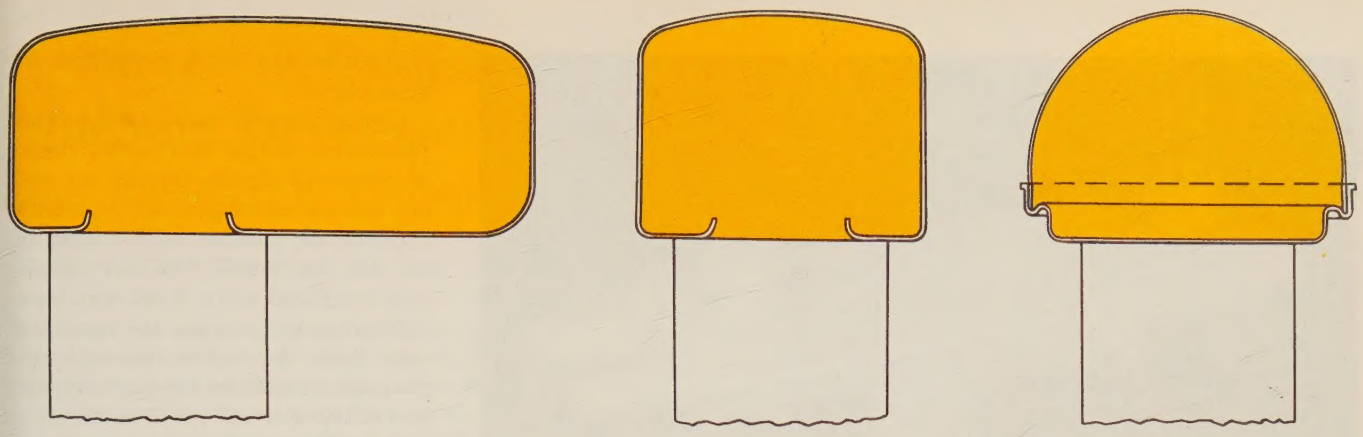


Fig. 3—End views of radiator top-tanks. The older tanks (left) were large and hung over the core face. The centered tank (center) provided ample coolant reserve for the system and structurally resisted deflection caused by pressure. The dome construction represented an even further improvement in resisting deflection.

Pressure caps and radiator filler necks were completely re-designed to provide a positive and dependable coolant seal and to insure continuous operation at temperatures in excess of atmospheric boiling (212° F at sea level). Overflow tube sizes were increased to permit adequate discharge under pressure conditions.

All of these design changes are a result of the gradual evolution of the pressure system which is now in almost universal use in the automobile industry.

Automatic Transmissions

Torque converter type transmissions, because of the necessity of limiting the maximum oil temperature resulting from slippage friction, must be equipped with heat exchangers (Fig. 4) which utilize the engine coolant liquid as a cooling medium.

Heat from the transmission oil is, therefore, absorbed in the cooling system and must be dissipated through the radiator. Unfortunately, the maximum heat input from the transmission occurs at the lower car speeds, where both liquid and air circulation through the radiator are at a minimum and the cooling capacity is greatly reduced. The effect on the cooling index from this source is in the neighborhood of 10° F to 12° F which must be compensated for in this amount to maintain the required cooling.

Supplementary Equipment and Accessories

Most supplementary equipment, such as power steering, power brakes, and large oil filters do not contribute directly to the heat load. They do, however, interfere with the normal air circulation and discharge because of their size and location. Thus, they indirectly cause a reduction in the cooling efficiency. Fresh air heater intake tubes, license plates, and twin horns also may have a detrimental effect on cooling through diversion or interference with the entering air stream.

Air Conditioning

Car refrigeration or air conditioning as currently installed presents the greatest increase in the cooling demand of the supplementary equipment group. The condenser, when mounted directly in front of the radiator, interferes with the free flow of air to the core. The air temperature after passing through it is increased, reducing the effective air-water differential.

Because of the increase in static pressure resulting from the entering air having to pass through both condenser and radiator core, the fan air delivery is considerably reduced. This reduction has to be compensated for by larger and more efficient fans, full fan shrouds, complete air seals around the radiator to prevent by-passing of any available cooling air, and, in some instances, increased fan speed.

Considerable attention has to be given to the idle cooling of air-conditioned cars. In order to maintain comfortable compartment temperatures, the system must continue to operate during periods when the car is temporarily parked for such purposes as shopping and doctor calls.

Increased Horsepower

Since World War II there has been a gradual trend toward higher-powered engines. In general, however, these power increases have been accomplished by higher compression ratios and advanced engine design, without penalizing the cooling system to any great extent with increased heat rejection.

In some instances, the heat rejection was substantially reduced permitting corresponding reduction in the radiator size and capacity.

Grilles

Most of the early post-war grilles penalized the cooling efficiency to some extent. As the cooling demand for other items increased, grille designs were improved and still further improvement may be expected by designs which offer even less restriction to the entering air stream.

Fans, Shrouds, and Air Seals

Much improvement has been accomplished in modern cooling systems, especially under low-speed and idle conditions, with new fan designs enclosed in complete shrouds. The shape, contour, and number of fan blades have been varied, diameters enlarged, and, in some instances, speed ratios increased.

Discussion

The basic rules governing the selection of the proper cooling index have had to be revised to some extent, primarily to include the factors affecting cooling resulting from design, equipment, and operational changes now incorporated in modern vehicles.

For many years, an *air-to-boil* index of approximately 100°-105° F at 30 mph and 115°-120° F at 60 mph under full-throttle operating conditions was selected by cooling engineers as a criterion for satisfactory cooling on passenger cars with world-wide distribution.

Under most all climatic conditions, this amount of cooling has proven to be adequate, especially on cars equipped with pressure caps. Such caps effectively reduce or eliminate the coolant losses so prevalent on atmospheric cooling systems during power surges or following steep mountain climbs.

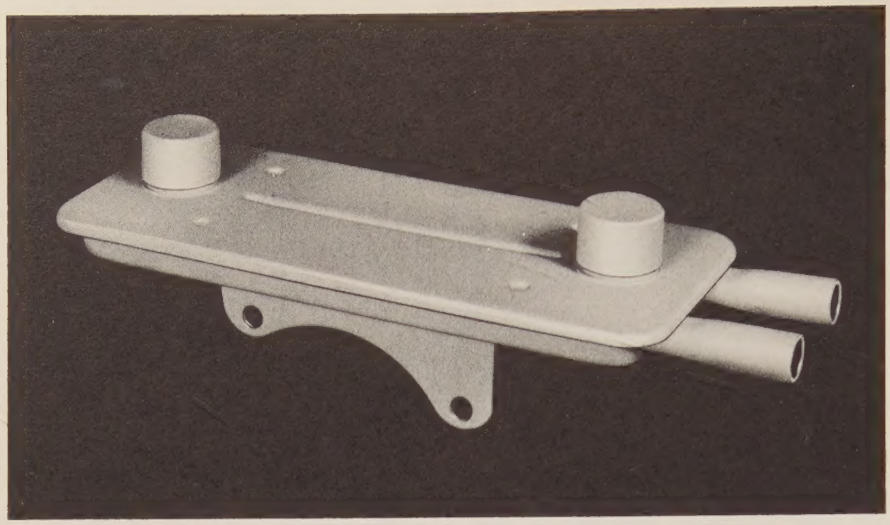
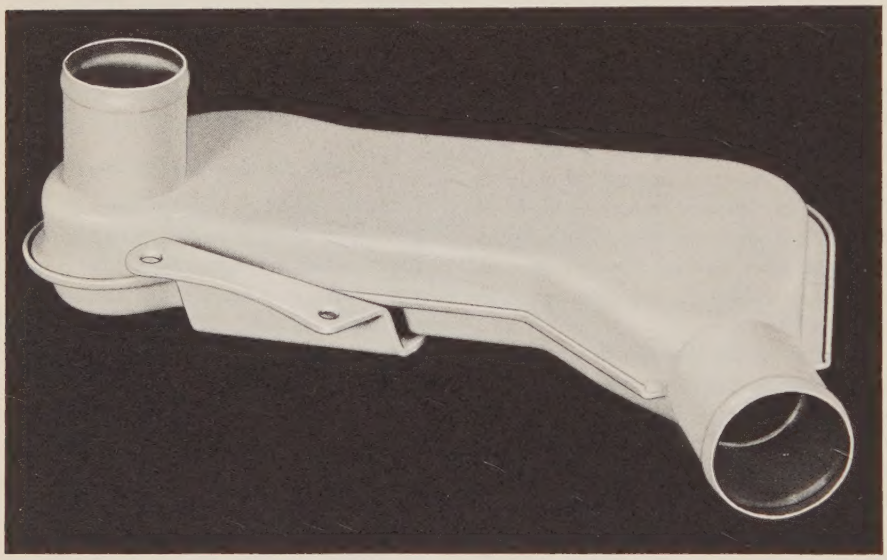


Fig. 4—Typical heat exchangers. Transmission oil is pumped into the devices and heat is transferred to the cooling-system coolant which finds a different path through the exchanger.



Modern cars equipped with high compression engines and operating at high cooling system pressures are sensitive to detonation, especially during rapid acceleration. Because of this, particular attention must be given to maximum operating temperature under high-speed, road-load conditions. On the contrary, low-speed, full-throttle cooling index becomes less important because of the tremendous acceleration possible with present-day power-weight ratios and automatic transmissions.

Most modern cars would experience very little difficulty in accelerating to speeds above 20 mph with full throttle even on the steepest mountain grades. When higher than 20 mph is not possible, due to traffic or road conditions, less than full throttle is required and the heat input is considerably less.

There is a popular misconception that all pressure systems operate at higher temperatures than atmospheric systems, due primarily to the presence of pressure. Actually, this is not true. However, pressure systems permit continuous operation without coolant loss when the coolant temperature exceeds the atmospheric boiling point of 212° F. Some cars have cooling systems designed to take advantage of the increased boiling temperature on which the radiator size and capacity has been reduced, and these obviously operate in a higher temperature range. For example, a 13 lb system boils at 243° F at sea level or 31° F higher than the atmospheric.

Cooling capacity may be reduced approximately one per cent for each degree of differential change between top-tank and ambient air temperature. In order to maintain the same *air-to-boil* cooling index, the core surface area and capacity may be reduced about 31 per cent. However, when this is done, the same heat input from the engine (*Btu/min*) that produced a stabilized top-tank temperature of 180° F would operate similarly at 211° F with the pressure system, and both would be 32° below their respective boiling temperatures. Nevertheless, the metal temperatures also would be correspondingly higher with the pressure system. Inasmuch as detonation is quite sensitive to metal temperatures, the relation of detonation and high-temperature pressure operation is quite clear.

Conclusion

Present-day cooling systems have kept abreast of the demands imposed by motor car design changes, supplementary equipment, and improved operational conditions. They have also incorporated numerous design changes which improve the overall efficiency and hold production costs to a minimum in the face of increased metal and labor costs.

Bibliography

Other related literature in this field includes the following:

Cooper, J. H., "Redesign: It'll Stretch Copper," *S. A. E. Journal*, Vol. 60, No. 5 (May 1952), pp. 63-4.

Holmes, J. R., "Current Status of Aluminum Auto Radiator," *Modern Metals*, Vol. 8, No. 5 (June 1952), pp. 33-4.

Hundley, R. A., "New Concept in Internal Combustion Engine Cooling," *S. A. E. Journal*, Vol. 58, No. 11 (November 1950), pp. 33-9.

Obert, E. F., *Internal Combustion Engines*, (Scranton: International Textbook Company, 1950; 2nd Edition), pp. 14-15, 290-94, 421-28.

Taylor, C. F. and Taylor, E. S., *The Internal Combustion Engine*, (Scranton: International Textbook Company, 1948; 2nd Edition), pp. 128-141.

————, *Radiator Material Substitutes*, (New York: Society of Automotive Engineers, 1952).

————, *Maintenance of Automotive Engine Cooling Systems*, (New York: Society of Automotive Engineers).

A Survey of Balancing Machine Developments in the Research Laboratories Division

By THOMAS C. VAN DEGRIFT
Research Laboratories Division

Precision balancing permits production accuracy

To the average automobile user, the terms *power roar*, *humming along*, and *throb of the engine* portray the feeling of power. To the engineer, these terms indicate unbalance, high bearing loads, and undesirable noise and vibration. Unbalance in rotating parts is caused by many factors not under the control of the designer. Special balancing machines and equipment have been developed in General Motors as tools for use in minimizing these factors.

In the early 1920's, engineers were more concerned about making the automobile move than they were about providing it with riding comfort. Then the closed bodies with four, six, and eight-cylinder engines came into existence with their greater speed. Along with them came the problem of eliminating amplified vibrations and rattles which had not been especially noticed before. Balancing of rotating automotive parts in the laboratory on special machines was the first step toward a solution. Designing and producing machines with laboratory accuracy for car production usage was the second.

For 30 years, the Special Problems Department of the Research Laboratories Division has studied and developed methods of accurately balancing rotating parts while the parts are being produced. Out of these studies has originated a line of basic balancing machines. Each series of machines was developed to balance a general type of part, with many variations possible to fit them for more specific types. These GM Research Laboratories balancing machines have been used for over 25 years in production, and more than one thousand are now in daily use here and abroad. Every General Motors Division which has the task of balancing rotating machinery uses this equipment.

The Meaning of Unbalance in Rotating Parts

There are many factors which are responsible for unbalance in rotating parts. Porosity of casting and variation in density of the material may cause unbalance even in parts that are symmetrical and machined all over. Wear in forging dies, shifts in casting cores, and variance within manufacturing tolerances in assemblies of parts are other causes.

The customary unit for measuring unbalance is the *ounce-inch*, which is one oz at a radius of one in. from the center of rotation. The centrifugal force due to unbalance increases as the square of the speed. Doubling the speed increases the force four times, and tripling the speed increases it nine times. For this reason, unbalance is of great importance in modern high-speed machinery; the unbalance force causes vibration, bending, gear noise, and high bearing loads.

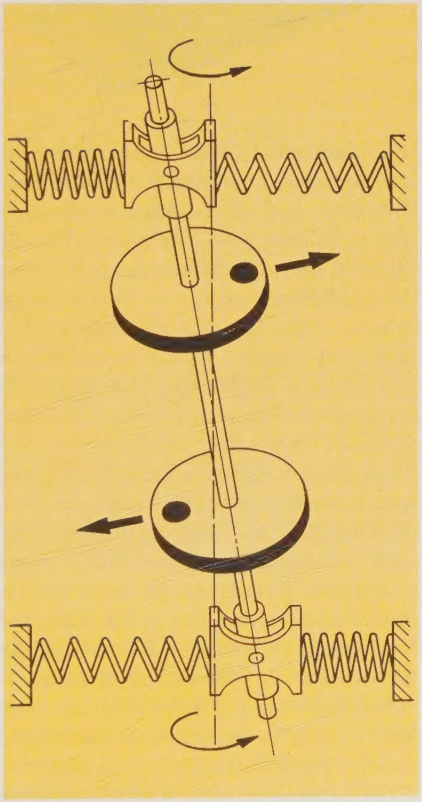


Fig. 1—In this illustrative case, the mechanism is rotating above the natural frequency of the spring supports. The center of gravity has shifted from the shaft centerline because of the unbalance weights on the discs. The shaft is now rotating about the new center of gravity and the eccentric wobble about this axis is proportional to the amount of unbalance.

If an object is suspended so that it is free to rotate without the confinement of journal bearings, it rotates about an axis passing through its center of gravity. The axis through the center of gravity may be called the *mass axis* of the object. If the object is symmetrical and in balance on its bearings, the mass axis and *geometric axis* coincide and the object can be made to rotate at high speed without vibration. If it is not in balance, the two axes do not coincide and the bearing describes an eccentric or wobbling motion (Fig. 1). *The magnitude of the eccentric motion is proportional to the out-of-balance magnitude of the object.* The dynamic balancing machine is designed around this principle.

The Origin of Balancing Machines in the Research Laboratories

About 1923, better roads, lower gear ratios, and other advances in automotive technology had brought about higher average engine speeds and higher road speeds. The automobile-buying public accepted the closed body and engine-transmission gains, but the acceptance was combined with the first real demand for even further refinements. Qualities which a few years before were important only for cars in the luxury class were being demanded by purchasers in the lower price class. Freedom from vibration was one of the foremost requirements, and the car manufacturing Divisions were emphasizing smoothness in their production plans for that year. A survey revealed that methods then used for balancing parts would over-tax the

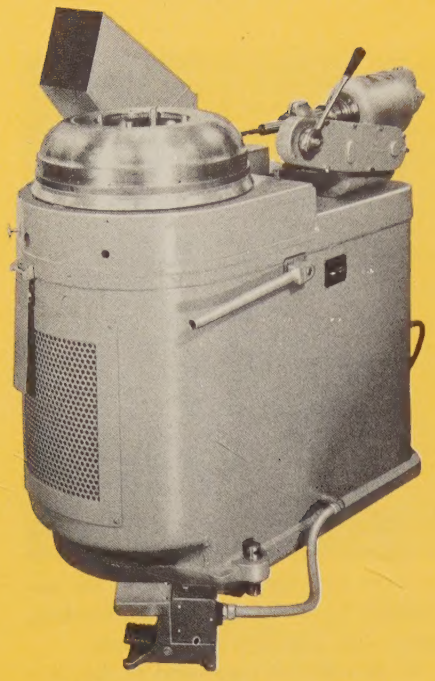


Fig. 2—A typical static balancing machine with built-in drilling equipment. used for balancing Buick torque converters where unbalance occurs in only one plane.

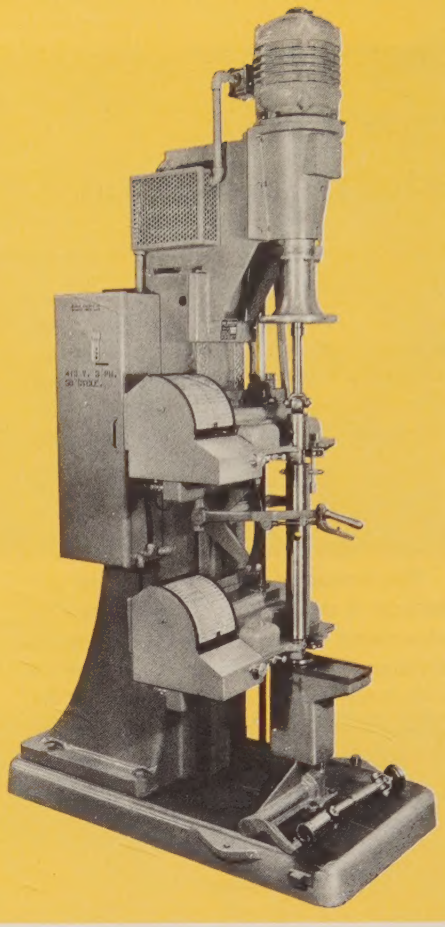


Fig. 3 (right)—One of the standard universal dynamic balancing machines in use by General Motors Holdens, Limited, Australia.

available balancing equipment, which was slow and costly and required the services of highly-skilled operators. The Research Laboratories Division was therefore requested to develop a balancing machine which would provide an accurate, simple means for balancing production parts. In 1926, three years after Research Laboratories engineers initiated the project, the first model of a *crankshaft dynamic balancing machine* was in production use at Buick Motor Division.

The balancing machine developed in the Laboratories, unlike most of the other Research developments, also has been produced for sale outside of General Motors. In this way, the Laboratories has been able to sustain a modern shop with facilities and attendant personnel available on short notice for other important research projects when the need arises.

The Research Laboratories balancing machine was entirely different from anything that had been built up to that time. To date, over 25 patents have been issued covering the different types of machines and their underlying principles.

The four basic types are Static and Dynamic Balancing Machines, Mass-Centering Machines, and portable Vibration Indicators. *Static balancing machines* are designed to statically balance discs, flywheels, and other similar parts where the unbalance is in one plane (Fig. 2). *Dynamic balancing machines* are used where the unbalance occurs in two or more planes along the axis of rotation. The universal dynamic balancing machine is the standard model which has been used in production since 1926 (Fig. 3). Other dynamic balancing machines in this class are the horizontal crankshaft, propeller shaft, armature, and propeller balancing types. The *mass-centering machine* is designed to center-drill a rough crankshaft forging on its mass axis to insure a low unbalance in the machined crankshaft. *Vibration indicators* are designed to study and analyze vibration in a machine after it is built. With the addition of suitable fixtures, they also can be used as portable balancing machines.

In several of the high production machines, provision is made for incorporating a drill press as an integral part of the balancing machine. This makes possible completely balancing a part without removing it from the machine, a feature which reduces handling time to a minimum. The indicator chart can be calibrated to read directly in drill depths, so that the operator, to achieve balance, needs only to read the unbalance value, stop his machine at the indicated angle, and drill to the required depth.

Balancing machines are designed in both vertical and horizontal form, depending on the weight, length, and diameter of the part to be balanced. Usually it is only necessary to build adapters and make minor changes in the basic machines to adapt them to a specific balancing operation.

Operation of the GMR Balancing Machine

Spinning and Tracing—
Key Words to Balancing

The principle used in all of the General Motors mechanical-type dynamic balancing machines to detect unbalance is to rotate the part on freely-suspended bearings, and measure the *runout* of the bearings. This runout, or off-center wobble, is a measure of the unbalance, and is directly proportional to ounce-inches, the unit of unbalance. As stated above, a part in perfect balance has no runout because its mass axis and geometric axis coincide; therefore, no unbalance forces are transmitted to its freely-suspended bearings.

General Motors Research Laboratories balancing machines have, since their beginning, used for detecting the magnitude of unbalance a light-ray indicating system. This system consists of a tilting mirror, a many-sided rotating mirror, and a calibrated screen (Fig. 4).

With these elements just mentioned, the indicator gives a direct reading of the amount and position of the unbalance, eliminating the need for reference to calculations, tables, or charts. On a dynamic balancing machine, indicators at both ends of the shaft take readings, giving the necessary correction for both static and dynamic balance. On the static balancing machine, only one indicator is required since balancing takes place in only one plane. When the amount and position of the unbalance is known in either machine, surplus metal is drilled out or ground off until the indicator shows no unbalance.

In some of the machines in which it is necessary to achieve greater precision, a cathode-ray oscilloscope is used. These machines will detect motions as small as 2.5 microinches (0.0000025 in.). This

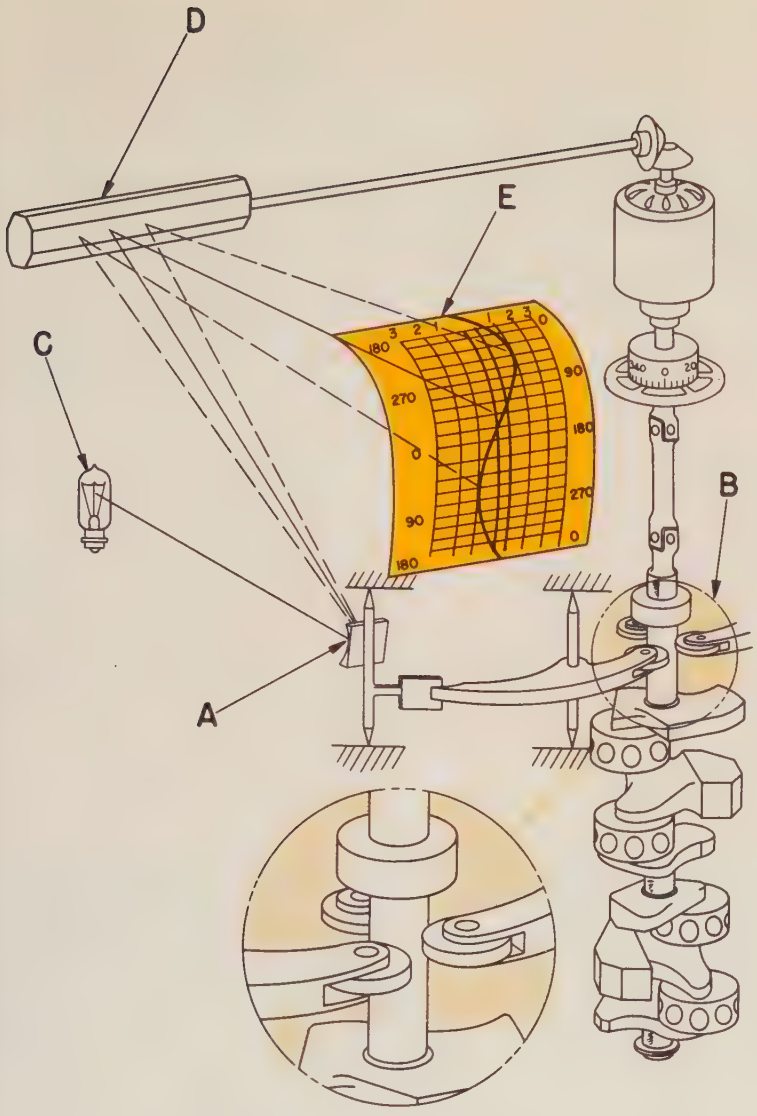


Fig. 4—Light-ray indicating mechanism used to obtain readings of the amount and position of unbalance which was developed for the balancing machine. The movement of runout of the bearings *B* causes the mirror *A* to tilt. The tilting mirror picks up the light beam from the light source *C* and reflects it onto the many-sided mirror *D* and from there, to the calibrated screen *E* as a spot of light. The spot of light is directed horizontally across the screen by the movement of runout of the bearings, and vertically by the rotating mirror in phase with the shaft rotation. The combination of these two movements traces a sine-wave on the screen when the shaft is out of balance. When the shaft is in balance, the light beam traces a straight vertical line. The screen is calibrated so that the peak of the sine-wave gives the angular position, the amplitude, and the amount of unbalance, either in oz-in. or drill depths.

method was developed for precision balancing of miniature gyroscope rotors and is now used also in balancing of high-speed turbine rotors. The sine-wave method of locating the unbalance, whether optical or electronic, has proven to be so popular that it has been maintained in practically all of the Research Laboratories balancing machines.

Early Use of GMR Balancing Machines in the Production Plants

After that first use of balancing machines in production plants in 1926 at Buick Motor Division, requests were soon received to balance Buick flywheels. Consequently, a vertical *flywheel dynamic balancing machine* was developed incorporating the sine-wave optical indicator and drilling equipment.

Some form of flywheel static balancing was in use in practically all of the car plants at that time. The method usually was to mount the wheel to be balanced on a balanced arbor. The arbor was then set on level knife edges and the wheel

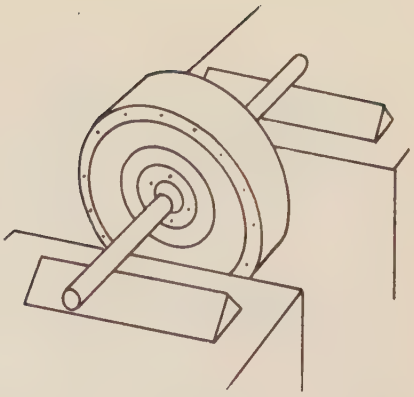


Fig. 5—Older method used in 1926 for balancing flywheels by mounting the wheel on a balanced arbor and then setting the arbor on level knife edges. The wheel was allowed to come to rest on the knife edges, permitting the heavy side of the wheel to swing to the bottom.

was allowed to come to rest on these knife edges (Fig. 5). This procedure permitted the heavy side of the wheel to swing to the bottom. This was a very slow operation and a production of ten wheels per hour was considered good.

The Buick flywheel of that time had a wide face, necessitating dynamic balancing; that is, it had to be corrected in two planes—an operation which could not be accomplished on knife edges. Four *flywheel dynamic balancing machines* delivered to Buick in 1927 reduced the time of balancing to approximately one-eighth of that required for the static, knife-edge balancing and, additionally, produced more accurately balanced wheels.

Many problems were confronted in the first machines. Even with the most careful adjustments, it was impossible to keep the shaft from going into a gyroscopic motion. This was remedied at first by using a damper on each roller arm (B of Fig. 4). The damper was in the form of an adjustable air dash pot. Later, a fixed 0.015 in. hole was used for metering the air and now both rubber and fluid-silicone dampers are used.

In some of the early machines the bearing surface between the crankshaft journal and the balancing machine was also a problem—and the roller construction came into being. The first design employed Durex or sintered, oil-impregnated bronze material which proved too soft, and then a phenol canvas gear stock was tried. This was satisfactory so far as wearing qualities were concerned but it was impossible to maintain a three-armed setup (the one shown in

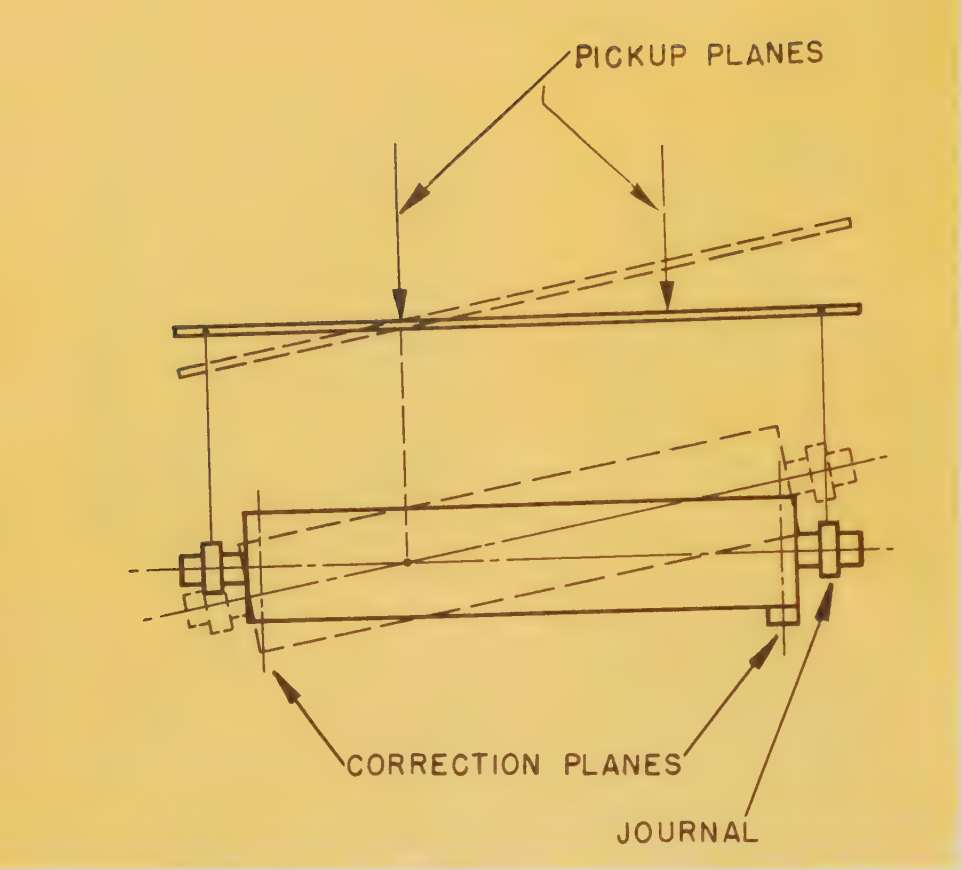


Fig. 6—Nodal bar indicator which was added to the machines to relay the true motions of the unbalance from each end of the shaft to the optical indicators.

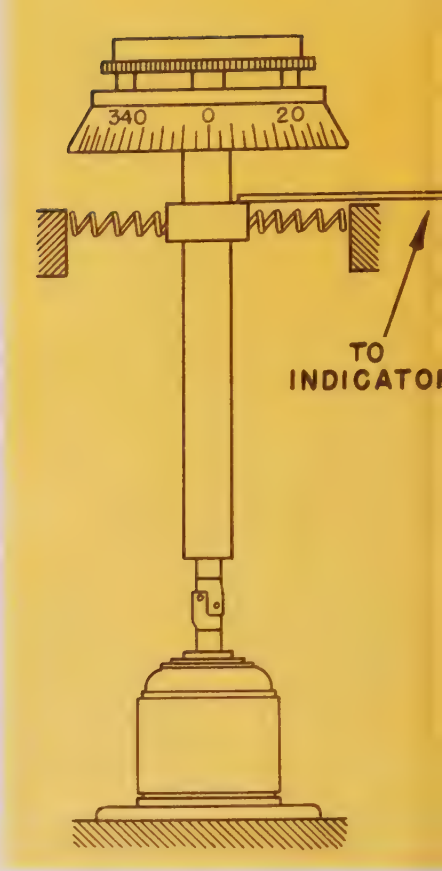


Fig. 7—Schematic drawing showing the basic principle of the rotating static balancing machine used to balance thin flywheels, clutches, and other parts of a similar size not requiring two-plane or dynamic couple correction.

Fig. 4 is one-armed) with the same type of lubrication. Consequently, the shaft would often drift, requiring constant adjustment of the light beam to the center of the indicator system. The problem was clearly one of friction between the balancing machine arm and the crankshaft journal. The roller was the solution. It was mounted on anti-friction bearings between the two elements and the arm is now known as the roller arm.

Another difficulty which also showed up was the effect of one end of the unbalanced shaft on the other end. This resulted in the addition of a small portion of the unbalance from one end of the crankshaft to the reading of the other end. This was at first fully compensated for by a mathematical system of unbalance correction. In the late 1930's, the difficulty was eliminated by the addition of an improved nodal bar indicator which permitted accurate readings for each end of the shaft being tested (Fig. 6).

As information about the first successes became available, Oakland Motor, Cadillac Motor Car, and Vauxhall next placed crankshaft dynamic balancing machines into use on their production lines.

Early in 1927, work was started on a rotating static balancing machine for thin flywheels, clutches, and other parts of similar size which did not require a two-plane or dynamic couple correction (Fig. 7). Until this time, very little attention had been given to the accurate balancing of clutches and related parts. This static balancing machine had a vertical spindle which was driven through a universal joint at its lower end. The part to be balanced was placed at the upper end which was free to move within a coil-spring-mounted bearing.

Shortly after that, a high-speed, light-ray indicator type *propeller shaft balancing machine* was built for Pontiac Motor Division, successor of Oakland. This machine took into consideration the shaft deflections due to speed and had a top speed of 3,000 rpm. These machines remain in use in some plants. In 1936 an entirely new concept of propeller drive shaft balancing was introduced. The new machine was much more sensitive and used fixed heads mounted on stiff cantilever springs which flexed less than 0.001 in. Vibrations caused by the unbalance forces were picked up by a tuned condenser circuit, and read on a cathode-ray oscilloscope. Shafts with rotational speeds up to 5,000 rpm were capable of being balanced with this machine.

Eighty of these new machines were built and today many large scale manufacturers and users of propeller shafts employ them either in production or in checking operations (Fig. 8).

Beginnings of Armature Balancing

While major attention was devoted to the balancing problems of the car manufacturing Divisions, the non-automotive Divisions were not overlooked. In 1928, a balancing machine was developed for Delco Products Division, Dayton, Ohio. Until then, fractional horsepower motor armatures were balanced on an imported machine which utilized pencil or stylus markings on a coating applied to the shaft journal. The General Motors *armature dynamic balancing machine* was actually a scaled-down vertical universal crankshaft dynamic type designed to take smaller rotors.

In spite of the careful dynamic balancing of each fractional horsepower electric motor at Delco Products, a

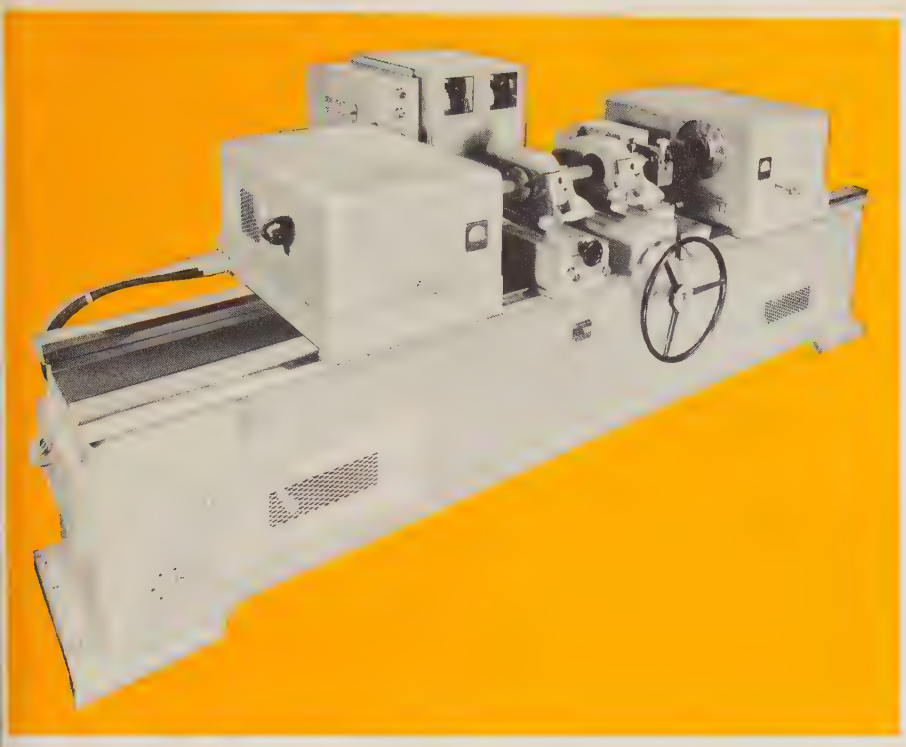


Fig. 8—High-speed, light-ray indicator type of propeller shaft machine used in production and checking operations for automotive and truck propeller shafts.

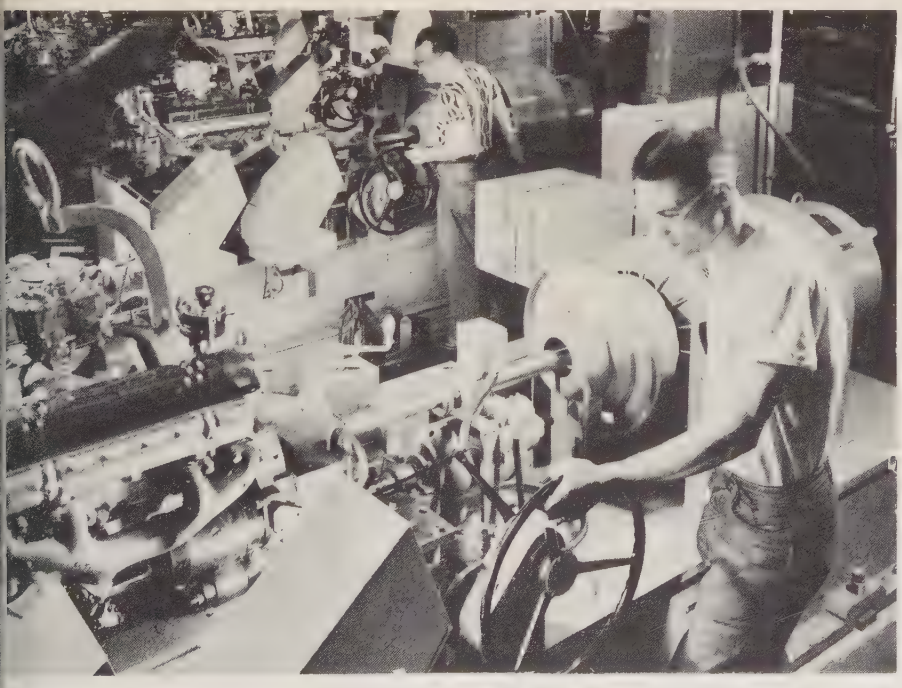


Fig. 9—Complete engine-assembly balancing machines in use at Buick Motor Division. The machines check any unbalance remaining in the engine after assembly with previously-balanced parts.

sizable percentage were rejected on the basis of feeling too rough to the inspector's "touch." These were then disassembled and the rotors returned to production for rebalancing. Of the returned rotors, 95 per cent showed no unbalance, raising doubt as to the sensitivity of the balancing machine.

As a result, a freely-suspended table was constructed on which to place each motor as it progressed down the final inspection line. The table responded only to the forces of unbalance in the motor and a light-beam indicator amplified

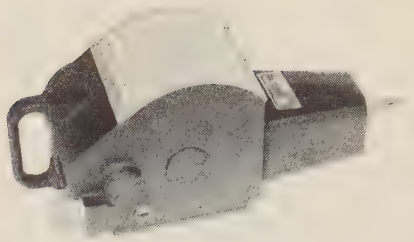


Fig. 10—One of the portable vibration indicator models used to balance parts in the plant.

the motion of the table making a few microinches visible. This fixture and indicator provided an accurate measure of the unbalance in an assembled electric motor, running without load at its normal operating speed. This showed that the rough motors which were previously rejected as showing no unbalance actually were vibrating from a torsional 60-cps vibration which moved the motor torsionally about its shaft axis. Use of the fixture demonstrated that an operator could not distinguish the 30-cps unbalance vibration (1,800 rpm) from the 60-cps torsional movement. Steps were taken then to correct the torsional disturbance by more quality control in windings.

Throughout the following decade, few armature balancing machines were added to the line until 1937 when the advent of the Diesel locomotive brought increased requests for this type of balancing. During that year, armature balancing machines developed ranged from small armatures for Delco Appliance Division to large armatures for Diesel locomotive generators weighing up to 12,000 lb.

Assembly Balancing

Prior to 1929, each part was balanced individually then assembled and installed in the engine. This method could not take into account the possible additive effects of any unbalance remaining in the individual parts. This could happen in the *limit stack-up*, the laboratory term for cumulative tolerances of any nature—such as when several discs might be mounted on a single shaft. Because of the additive effect of tolerable unbalance forces in individual items, the unbalance force in the assembly might be over tolerance and a rough engine could result.

To handle the limit stack-up problem, the design of the machine was altered to permit the crankshaft, flywheel, and the

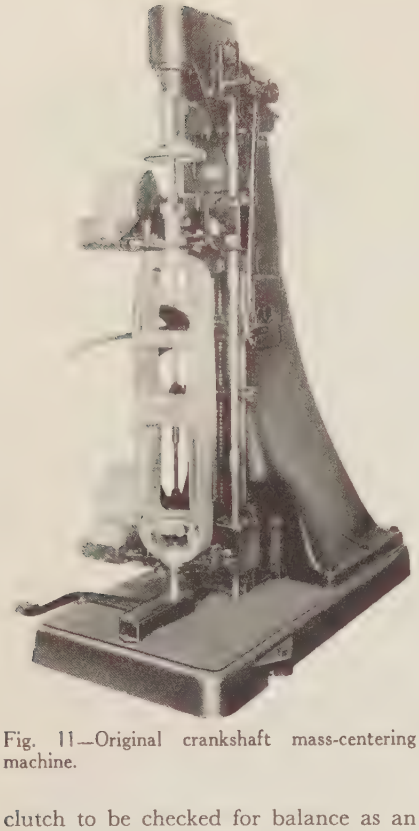


Fig. 11—Original crankshaft mass-centering machine.

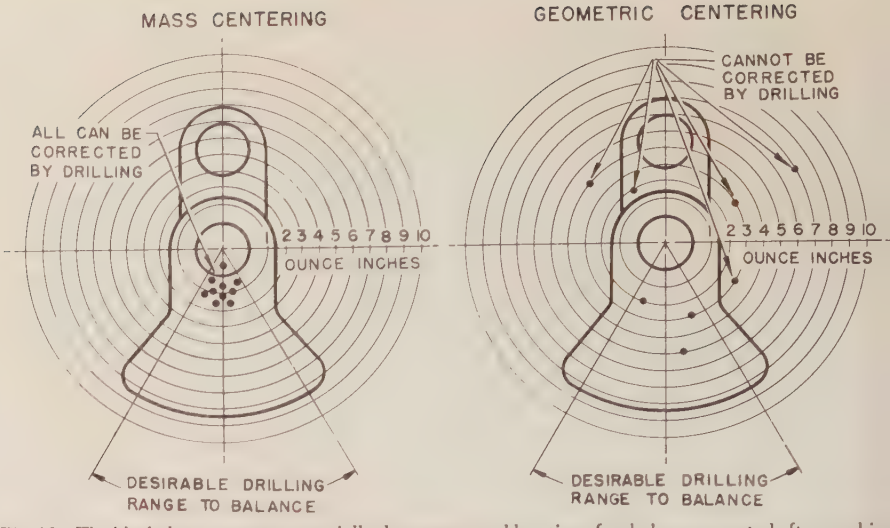

MASS CENTERING
ALL CAN BE CORRECTED BY DRILLING
1 2 3 4 5 6 7 8 9 10
OUNCE INCHES
DESIRABLE DRILLING RANGE TO BALANCE
GEOMETRIC CENTERING
CANNOT BE CORRECTED BY DRILLING
1 2 3 4 5 6 7 8 9 10
OUNCE INCHES
DESIRABLE DRILLING RANGE TO BALANCE

Fig. 12—The black dots represent vectorially the amount and location of unbalance expected after machining with the two methods of centering crankshaft forgings prior to machining. Note that with the mass-centering technique all remaining unbalance corrections fall within an angle permitting easy balance correction by drilling into the counterweight. The largest unbalance to be corrected is less than 1½ oz-in. Some crankshafts will need no correction. With the geometric-centering technique, larger amounts of unbalance result and only a portion of the crankshafts can be corrected by drilling into the counterweight. The rest will need to be snag-ground, a more difficult and far more inaccurate method of removing unbalance.

clutch to be checked for balance as an assembly rather than as individual parts. This insured well-balanced assemblies of the major rotating parts in the engine.

It was not until 1939 that a complete *engine-assembly balancing machine* was built. This machine checked any unbalance remaining in the engine after it was assembled with previously balanced parts, and was provided with drilling equipment to correct the unbalances which had accumulated (Fig. 9).

The Development of a Portable Indicator

The early work in balancing machines indicated the need for a *portable vibration indicator* which could be transported as a trouble-shooting device to the plants to balance parts of a size impractical to move into the shop or laboratories (Fig. 10). This type of indicator has many uses where it becomes necessary to amplify small movements 75 to 500 times actual motion. Since a light beam has no inertia, it follows vibration amplitudes easily. Accordingly, the same optical system previously described was simply enclosed in a portable case form. A probe was added which, when placed against the part to be balanced, picked up the oscillation. This movement was, in turn, transmitted to the tilting mirror and the unbalance recorded by means of the optical system.

Beginning of Mass Centering

About 1931, Pontiac was devoting considerable attention to the final balancing of crankshafts. The location where the metal was to be removed varied. Sometimes it fell at an angle which did not permit drilling in the counterweights to correct the unbalance and some crankshafts were weakened by the removal of a surplus amount of metal. At that time, crankshaft forgings were finish machined from centers located geometrically from the main journals and the pin bearings of the rough forging. After studying the problem, it was decided to try an entirely new method of centering which would facilitate locating the center drilling from the center of mass of the crankshaft forging.

A special cradle was constructed for use in the *vertical universal crankshaft dynamic balancing machine*. Adjustable screws were incorporated to hold the crankshaft and adjust it relative to the cradle. The operation of *mass centering* as it was called (centering actually was about the center of gravity or mass axis of the shaft), was roughly as follows:

The mass centering cradle was first placed in good, or neutral, balance. The rough forging was then clamped in the cradle and the balancing machine run to determine the location and amount of unbalance in each end of the assembly. The machine was stopped and the crankshaft forging shifted in the cradle by means of the adjustable screws to make the correction for the unbalance noted. This operation was repeated several times until the total unbalance of the cradle and crankshaft was under one oz-in. The assembly of cradle and crankshaft was then removed from the balancing machine and placed on vee blocks in a conventional double-ended horizontal centering machine, and center drill holes made in the crankshaft forging. This was the origin of the *mass-centering machine* (Fig. 11).

This method immediately showed errors in forging die practice which were corrected at the start of the forging production run and consistently re-checked during the life of the die. These mass-centered crankshafts required only a minimum of balancing. The unbalance remaining after machining was always in a location convenient to correct by drilling (Fig. 12).

Further refinement of the mass-centering machine resulted in an improved model which eliminated stopping the machine for manual shifting of the crankshaft mass. This was accomplished by using small, reversible-type motors for shifting which were operator-controlled by means of pushbuttons. Drill spindles were also incorporated into the machine so that the center drill hole in each end of the shaft could be drilled without shifting the cradle into another centering

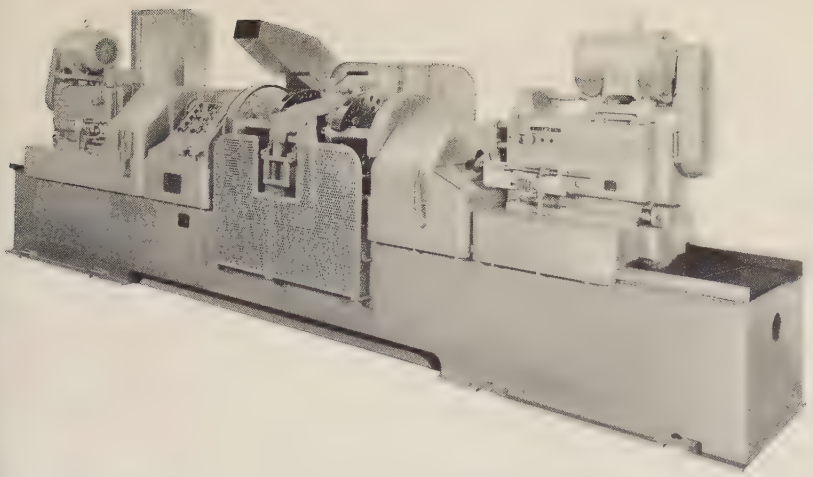


Fig. 13—The current mass-centering machine used to balance crankshaft forgings.

machine (Fig. 13).

Today, over 80 per cent of all automotive crankshafts made in the United States are mass centered on General Motors equipment.

First Commercial Production of Balancing Machines

Numerous requests from outside companies to purchase Research Laboratories balancing machines prompted management to permit the sale to non-General Motors companies beginning in 1932. The first customer used a special machine to balance windshield wiper motors, and the following year, a car manufacturer purchased a crankshaft balancer. From that year forward, the requirements of outside companies have been considered along with the requirements of General Motors.

Another commercial development of balancing machines was for General Motors Holdens, Limited, Australia, for whom six dynamic and rotative static-type machines were built to balance all of the rotating parts in its new car model.

Additional machines constructed during the years for the car producing Divisions have been balancing machines for water pump impellers for Oldsmobile Division and a machine of the horizontal spindle type for Cadillac Motor Car Division to test road wheels and tires. In 1937, a special machine was developed for balancing ship propellers with clearance to swing a 48-in. diameter propeller wheel. Portable light-ray vibration indicators were used as pickups.

Sales to outside companies are continuing and a total of 26 types of machines have been developed to date for both General Motors and outside use.

Wartime Uses of Balancing Equipment

During World War II, the emphasis was entirely on balancing projects for military use. The Allison 12-cylinder aircraft engine needed its supercharger rotor balanced to close limits in order to reduce bearing loads to tolerable limits. This resulted in the development of a line of electric pickup machines capable of reading to 0.005 oz-in. using the cathode-ray oscilloscope as an unbalance indicator.

In 1942, the Bureau of Ships requested the Research Laboratories Division to study the problem of balancing ship gyro compass rotors and develop a better method. These rotors weighed approximately 50 lb each and normally rotated at speeds of 8,000 and 11,000 rpm. At that time, they were being balanced by the cut-and-try method of suspending the rotor from a ⅛-in. cable and slowly bringing it up to speed. The shaft was marked for unbalance with a crayon (Fig. 14). It sometimes took several days to balance one rotor by this method, and there were only a few men in the country sufficiently skilled to balance them to the required limits. After a development period, the Research Laboratories Division was given a contract to build machines for use in Navy Repair Depots all over the world. The machine developed was a dynamic balancing machine providing a combination slow-speed 600-rpm roughing operation and a high-speed finishing operation of 5,000 rpm, complete with drill spindles to remove the unbalance. A production of three to four parts per hour was considered normal.

Other wartime uses of balancing machines were for balancing torpedo rotors, aircraft steering gyro rotors, turbine rotors, and a machine to measure the amount of precession in gyro gimbals. The smallest machine built was for a control disc used in an automatic gun sight. General Motors also provided the Navy Department with special light-ray type indicators to modernize balancing equipment for destroyer and battleship propellers. One experimental machine was developed to study the effect of balancing on ballistic accuracy of shells.

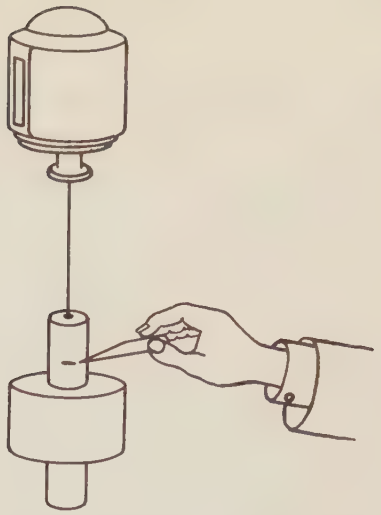


Fig. 14—Older method of balancing ship gyro compass rotors. The rotor was suspended from a ⅛-in. cable and slowly brought up to speed, while the shaft was marked for unbalance with a crayon.

Summary

Through the years, General Motors Research Laboratories has adapted the balancing machine principle to a wide variety of balancing problems. Several years ago, a survey showed that there are 66 parts in the automobile which must be balanced to close limits. Dynamic balancing equipment suitable for balancing almost any conceivable part has been developed in the Special Problems Department. The General Motors machines have many advantages. They require little floor space and are simple to operate. They have a high production rate and few machines are required. They are highly accurate and can hold close production limits.

In addition to providing balancing machines for General Motors Divisions, the Research Laboratories also makes them available to outside concerns. The Special Problems Department does the complete engineering design and development of balancing machines. The Department also acts in a consultant capacity on new problems in balancing which are arising constantly.

The Effect of Combustion-Chamber Shape on Smoothness of Power

When the average automobile customer considers the engine of his new car, he usually thinks of it in terms of four qualities: power, reliability, economy, and smoothness. The type or size of the engine are of interest to him only insofar as they satisfy his desires for these four principal qualities. To meet the customer's requirements, automotive engineers devote attention, therefore, to better engine designs. They constantly seek to improve such mechanical features as valve and cylinder arrangement, combustion-chamber shape, and compression ratio. These improvements increase the thermal, mechanical, and volumetric efficiencies of an engine, thus increasing power and fuel economy. The real challenge to the automotive engineer of today is to design an engine of high output and high efficiency that operates smoothly at all loads and speeds.

SMOOTHNESS in an automobile engine means that combustion roughness and detonation are absent or under good control. Combustion roughness is commonly observed as an objectionable or disagreeable engine vibration which can be detected inside the passenger compartment. Detonation is observed as a metallic knock or ping.

Combustion roughness is controlled by using a combustion-chamber design which avoids a high rate of pressure rise by effecting a lower rate of burn, and by designing more rigid crankshaft and crankcase structures. Detonation is controlled by increasing the quality of the fuel, by increasing the turbulence in the combustion chamber, by increasing the rate of burn, and by cooling the last part of the charge to burn.

Besides the above-mentioned principal considerations, engine smoothness is dependent upon several of the characteristics of an internal-combustion engine. A clear understanding of smoothness, therefore, is best obtained by considering the basic principles of power output and of combustion-chamber design.

Basic Principles of Increasing Output and Efficiency

The power output of an internal-combustion engine of given displacement can be increased by improving one or more of the three basic efficiencies:

- Volumetric efficiency
- Mechanical efficiency
- Thermal efficiency.

Volumetric efficiency may be improved by:

- Designing a freer induction system
- Increasing the charge density by minimum use of heat in the induction system
- Reducing restriction of flow through valves
- Designing intake manifold to take advantage of resonant tuning and ram effect
- Reducing exhaust back pressure.

Mechanical efficiency may be increased by:

- Reducing friction of pistons, rings, and bearings
- Reducing rubbing velocities of these parts
- Reducing pumping losses
- Reducing power requirements of parasitic power-absorbing units, such as fans, pumps, and generators.

Thermal efficiency may be increased by:

- Increasing compression ratios
- Reducing heat losses to cooling water and exhaust
- Utilizing optimum air-fuel ratio
- Optimum control of rate of burn by combustion-chamber design.

Increasing the volumetric efficiency or the mechanical efficiency does not directly affect smoothness. On the other hand, many of the factors affecting thermal efficiency have a great deal to do with smoothness. This discussion is confined to the factors affecting smoothness.

Combustion-Chamber Characteristics

Extensive research work has been done on experimental single- and multi-cylinder Cadillac engines having various combustion-chamber shapes. The work was done in order to arrive at a chamber design capable of high compression and high efficiency without engine roughness. The result of this study was Cadillac's *wedge-type*, turbulent combustion chamber. Fig. 1a shows the 1953 chamber design at 8.25:1 compression ratio. The wedge-shaped chamber was first introduced in the 1949 engine, having a compression ratio of 7.5:1. Since the designers of racing cars and aircraft engines have proved the excellent high output characteristics of the non-turbulent, *hemispherical* combustion chamber, careful consideration was given this design (Fig. 1b). In analyzing these two types of combustion chambers, it is significant to compare the following characteristics:

- Power output
- Detonation control
- Control of rate of burn
- Combustion roughness
- Future limitations.

By HARVEY L. MANTEY
Cadillac Motor
Car Division

Desirable $hp = V(KW - K_1AV^2)/375$

plus subjective factors

not found in equations

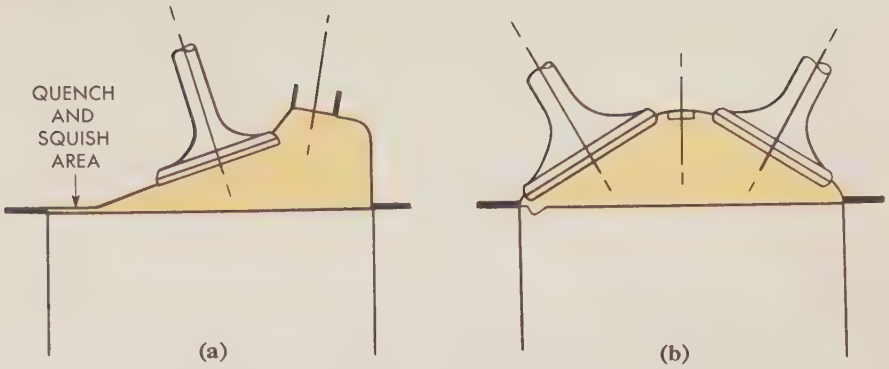


Fig. 1—Wedge-shaped, turbulent chamber (left) and hemispherical, non-turbulent chamber. These are two of many chamber designs tested in the development of present Cadillac combustion chambers.

ower Output

Laboratory tests on various valve-in-ead combustion chambers have shown iat the best ultra-high-speed power haracteristics were obtained with a emispherical chamber with the *vee* valve rrangement, as shown in Fig. 1b. This haracteristic makes the hemispherical hamber very desirable for race-car ap-lication.

High-speed power, however, is of little alue for automotive application because oad-car tests have indicated that engine peeds above 4,500 rpm produce objec-ionable noise and vibration. Fig. 2 shows ie horsepower of the 1953 Cadillac ngine (210 hp at 4,150 rpm) and an xperimental Cadillac engine (250 hp t 4,800 rpm). Road-car tests with the xperimental engine showed only small ains in performance over the standard ngine when normal gearing was em-loyed. Higher gearing improved the erformance of this engine, but engine oise was objectionable.

)etonation Control

Engine output and thermal efficiency ncrease with the compression ratio, but ie maximum compression ratio is lim-ed by detonation with commercially-vailable fuels. Detonation is a result f the almost instantaneous combustion f the last part of the charge. The haracteristic knock of detonation is aused by the vibration of the cylinder alls due to extreme pressure gradients et up within the combustion chamber. The intensity of the knock is dependent n the per cent of weight of the charge iat is burnt in this final compression-gnition process.

Pre-ignition is another type of uncontrolled combustion. In pre-ignition the charge is ignited by incandescent combustion-chamber deposits or *hot spots* before the normal spark occurs. Pre-ignition has the same effect as an over-advanced spark.

Present Theories Concerning Detonation

Gasoline and air mixtures of inflammable proportions self-ignite if compressed to sufficiently high temperatures and pressures. However, there is a definite length of time required, depending on temperature and pressure, to complete the necessary physical and chemical preliminaries for the process to occur.

In a running engine, compression increases the temperature of the combustible charge. The combustion process further compresses the unburned fraction to such a degree that the self-ignition temperatures of the last fraction to burn are always attained long before the flame from the ignition spark reaches it. However, it is the time lag in the combustion of the last part of the charge (Fig. 3) which enables the flame front to pass through the last part of the charge and therefore burn it in a normal manner before detonation can occur.

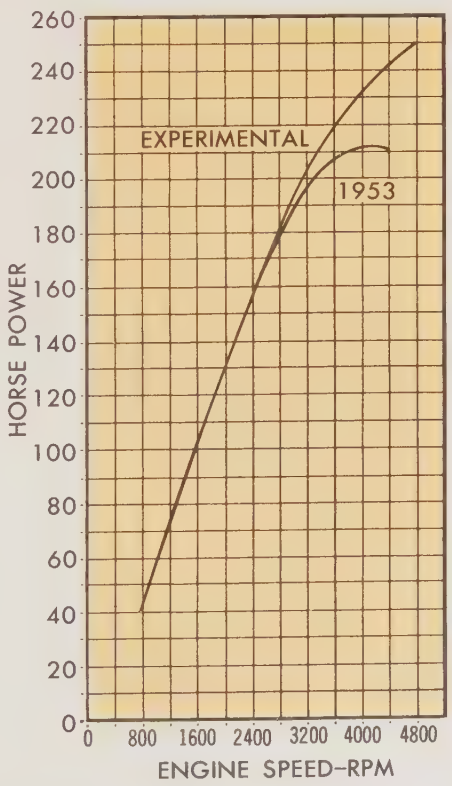


Fig. 2—Curves of full-throttle power of 1953 and experimental Cadillac engines.

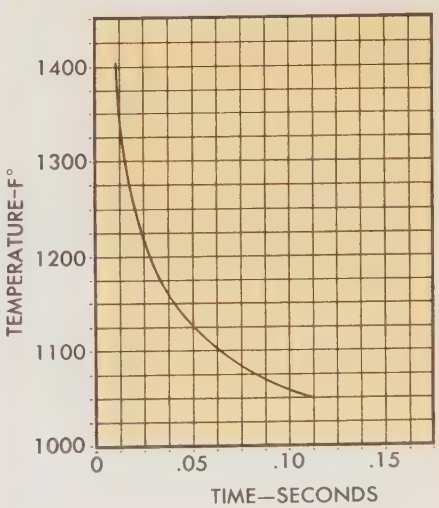


Fig. 3—Curve of the effect of temperature on combustion time.

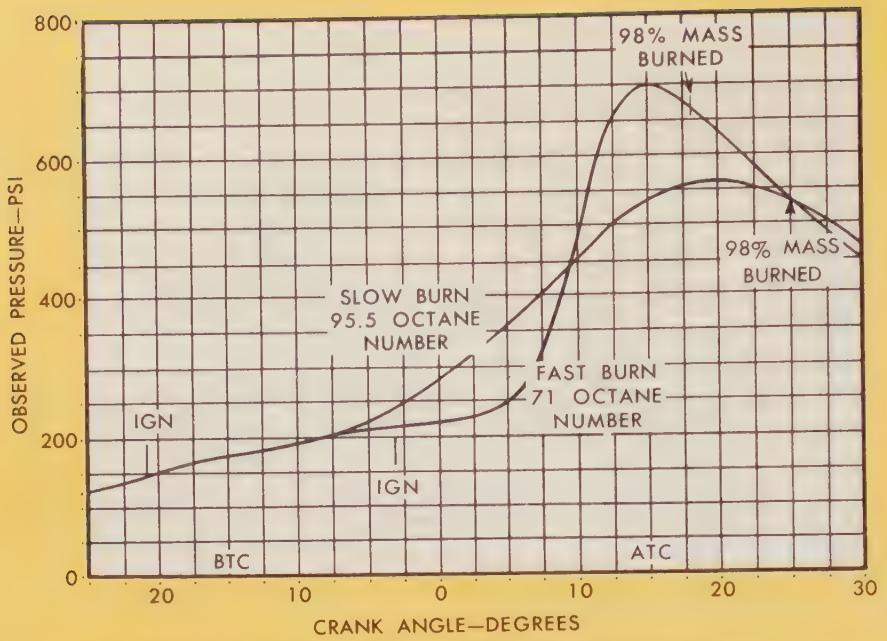


Fig. 4—Curves of crank angle vs. pressure of a fast and slow burning chamber.

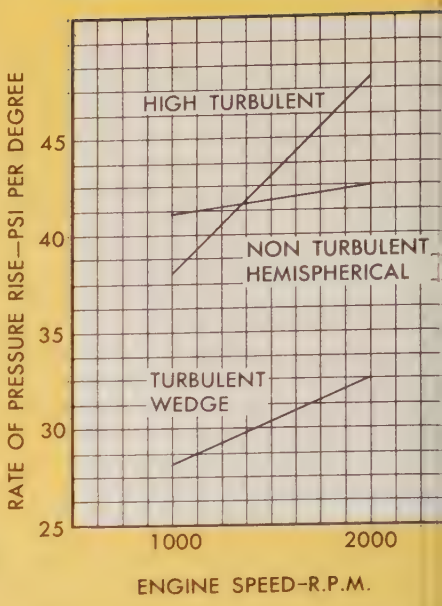


Fig. 5—Curves of maximum rate of pressure rise in cylinder vs. engine rpm for three types of compression chambers.

The quality of the fuel plays an important part in detonation control. Fuels are rated in *octane numbers* which are indices of their relative immunity against the tendency to detonate. A fuel of high octane is essentially a fuel having a high ignition temperature. The only way to eliminate detonation is to prevent the last part of the charge from attaining the ignition temperatures before the flame front has reached it. This condition can be improved by several means:

- Lowering the temperature of the entering charge
- Lowering the jacket temperature
- Cooling the last part of the charge
- Decreasing the combustion time
- Providing optimum air-fuel ratio for each load-speed condition
- Minimizing combustion-chamber deposit accumulation
- Increasing the turbulence of the mixture.

Mixture Temperature

Lowering the temperature of the entering charge helps to lower the temperature of the end gases in combustion. In practice, however, the charge is preheated in the intake manifold to about 130° F at part throttle for better mixing of the charge. This pre-heating provides for successful ignition of much leaner mixtures at part-throttle operation with some sacrifice to octane requirements at full-throttle operation.

Jacket Temperature

Lowering the temperature of the water jacket also helps to lower the temperature of the end gases in combustion. Laboratory and field tests have indicated that jacket temperatures below 150°F produce excessive amounts of water and sludge in the crankcase; hot water heater performance is also poor. High jacket temperatures also improve mixing of the charge during lean, part-throttle operation.

In practice, therefore, jacket temperatures are normally held at 165° to 185°F.

Uniform temperature distribution in the water jacket, however, is essential for detonation control. Localized hot spots due to poor cooling can greatly increase the octane requirements of an engine.

Quench Area

A more practical control of detonation is to provide a means of enabling the last part of the charge to burn normally. The heat generated by compressing the end gases must be conveyed quickly from the charge by conduction and radiation. This can be accomplished by having combustion end in a shallow section of the combustion chamber called the *quench area* (Fig. 1a). This section of the combustion chamber also can serve as the turbulent or *squish area.* (Squish is a laboratory word derived from *squeeze.*) Laboratory and road tests have shown that the shallower the section, the more effective it is in controlling detonation. Because of thermal expansion and inertia elongation of the reciprocating parts, about 0.040 in. is the lowest practical clearance that can be used in the quench area in normal-size engines. Since the exhaust valve area is the hottest part of the combustion chamber, it is clear that combustion should never end near the exhaust valve.

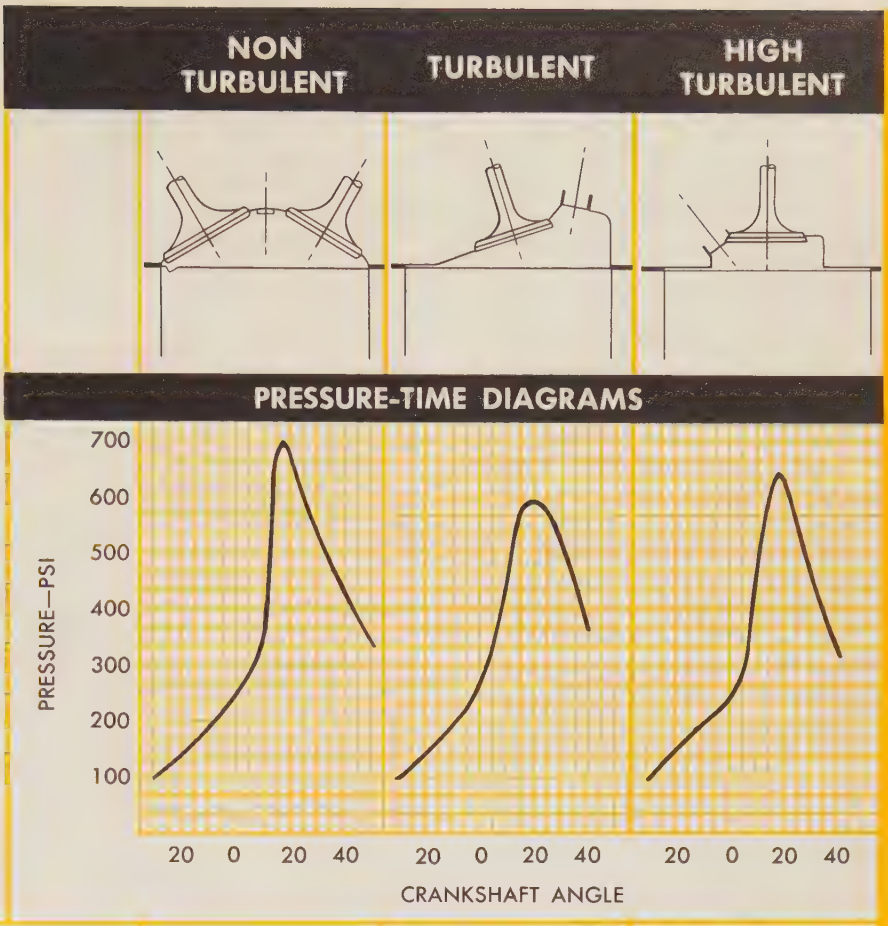
Rate of Burn

Many research studies have shown that the octane requirements of a spark-ignition engine decrease as the combustion time is decreased. The time for combustion can be shortened by: (a) compact chamber design, (b) high turbulence in the combustion chamber, (c) placing the spark plug near the center of mass of the charge, and (d) increasing engine speed.

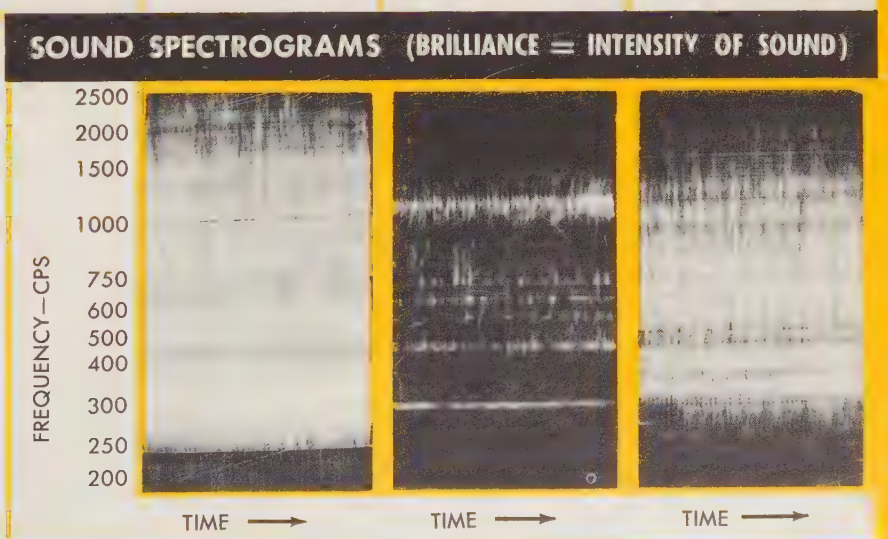
Laboratory tests on various valve-in-ead combustion chambers at 9:1 com-ression ratio have shown that full-hrottle octane requirements range from 0 to 100. This difference in octane equirements has been termed *mechanical tane numbers*. The combustion chambers ith the fastest rate of burn have con-stently shown the lowest octane require-ents and the greatest combustion oughness. Fig. 4 shows the crank ngle-pressure relationship of a fast and f a slow burning chamber.

Dynamometer tests have proved that he detonation control of a turbulent hamber is superior to a non-turbulent, emispherical chamber with the same ombustion time because:

- The hemispherical chamber has a higher peak pressure and, consequently, is more sensitive to ignition by compression.
- The hemispherical chamber has no quench area to cool the last part of the charge.



		NON TURBULENT	TURBULENT	HIGH TURBULENT
CHAMBER COMPRESSION RATIO		9:1	9:1	9:1
MAXIMUM RATE OF PRESSURE RISE	PSI/DEGREE CRANK ANGLE	41	28.2	38
SPARK ADVANCE		16°	16°	12.5°
OCTANE REQUIREMENT—95% POWER		96.3	93	70
OCTANE REQUIREMENT—99% POWER		99.8	97.5	90



ig. 6—Characteristics of non-turbulent, turbu-nt, and high-turbulent combustion chambers perated in experimental engines. These are typi-l of several combustion-chamber designs tested. f special interest are the un-retouched photo-raphs of sound spectrograms, in which intensity brilliance (white) is an indication of sound tensity at the frequencies indicated.

ombustion Roughness

Combustion roughness has been ob-rved as an objectionable or disagree-ble engine noise which can be detected side the passenger compartment. This oise lies chiefly in the frequency range

between 400 and 1,500 cps, with the most objectionable components lying in the range of 800 to 1,200 cps. Experimental data indicate that the exciting force of this noise is caused by: (a) the rate of pressure rise in the cylinder during combustion, (b) the rate of change of pressure rise during combustion, and (c) the peak pressure in the cylinder during combustion.

The vibration is transmitted from the combustion chamber down the connecting rods to the crankshaft, and also through the cylinder head and block to the external surfaces of the engine.

Control of roughness may be accomplished with good combustion-chamber design which, in turn, controls the exciting force of the noise. Roughness also may be reduced by developing more rigid crankshaft and crankcase structures.

The rates of pressure rise in the cylinder are increased with higher compression ratios, higher turbulence, more compact chamber design, and with the spark plug located near the center of mass. Since turbulence will vary with speed, the degree of turbulence of any combustion-chamber design can be determined by observing the change in the rate of pressure rise over the speed range. Fig. 5 shows this relationship (rate of pressure rise vs. speed) for the highly turbulent, turbulent, and non-turbulent chambers which are illustrated in Fig. 6. Fig. 5 indicates that the degree of turbulence is a function of the slope of the curve.

In order to obtain satisfactory detonation control in the maximum indicated mean effective pressure *IMEP* speed range with a non-turbulent combustion chamber, the chamber must be compact and the spark plug must be near the center of mass of the charge. This combination results in high rates of pressure rise and accompanying combustion roughness at low engine speeds. Low-speed roughness is very objectionable in the passenger compartment of a vehicle because the general noise level normally is low at low speeds.

Fig. 6 summarizes the octane requirements and combustion roughness characteristics of the highly turbulent, turbulent, and non-turbulent chambers at 1,000 rpm. Several significant items are illustrated in this figure. The turbulent chambers show lower rates of pressure rise and also lower octane requirements. Since the rates of pressure rise are lower, the combustion roughness noise is lower, as illustrated by the sound spectrograph of Fig. 6.

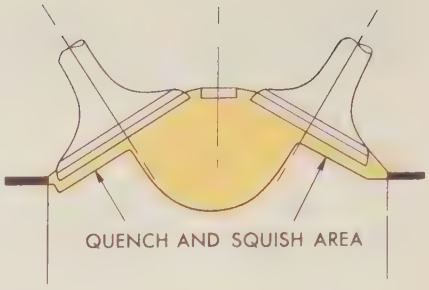


Fig. 7—A turbulent, hemispherical chamber. Studies and tests of this design indicated that, when sufficient space was allowed for valve clearance, the degree of turbulence was low.

Since best detonation control is achieved with a fast-burn chamber, the optimum combustion-chamber design is one that produces a fast, uniform rate of burn. This can best be achieved with a turbulent chamber and with the spark plug positioned in a highly turbulent section, thus starting the combustion process rapidly. The compactness of the chamber can then be made to give satisfactory rates of pressure rise without excessive combustion roughness.

Future Limitations

Limits on Compression Ratio

The foregoing discussion has shown that when the spark plug is located near the center of mass of the charge in the hemispherical combustion chamber extremely high rates of pressure rise occur at low engine speeds, resulting in combustion roughness. When the spark plug is moved to reduce the rates of pressure rise, detonation control is sacrificed. Some turbulence can be designed into the hemispherical chamber (Fig. 7) but because of valve position and possible valve-gear misbehavior, the clearance between the piston and head must be at least 0.150 to 0.200 in. Laboratory tests have shown that squish clearances must be less than 0.100 in. to produce noticeable turbulence.

The rate of burn and, consequently, the combustion roughness increases with increased compression ratio.

The poor control of the hemispherical chamber over combustion roughness severely limits this chamber for future compression ratio increases in automotive application.

Limits on Structural Parts

Road-car tests on an engine with a hemispherical combustion chamber and a tightly coupled transmission showed objectional low-speed roughness at 7.5:1 compression ratio and severe roughness above 8.25:1 compression ratio. Similar road tests on an engine with a turbulent chamber have been run with compression ratios as high as 12:1 with only a trace of roughness.

Although increased rigidity of the engine structure reduces audible combustion roughness, an increase in weight and cost usually accompanies any effort to increase rigidity. Extreme rates of pressure rise result in shorter durability limits of pistons, rings, and bearings.

Type of Transmission

Low engine speed is the key to good road-load fuel economy as shown in Fig. 8. This is satisfactorily done with a tightly coupled automatic transmission and low axle gearing, or low N/V ratio. (This ratio relates engine rpm and vehicle speed.) This curve infers that any transmission that increases engine speed during light to moderate accelerations results in unnecessarily increased friction and, consequently, fewer miles per gallon.

Road-car tests were run on wedge and hemispherical combustion chambers at 7.5:1 compression ratio with tightly coupled transmissions to evaluate the engine roughness characteristics of these two chambers. The wedge chamber showed no noticeable roughness at any speed while the hemispherical chamber showed objectionable engine roughness at medium to heavy-throttle operation at low engine speeds.

With the hemispherical-chamber test car it was necessary to increase engine speeds considerably and reduce throttle opening to attain acceptable smoothness. This necessitated a high stall-speed, converter type of transmission.

Acknowledgment

The author wishes to acknowledge help from the engineers of the General Motors Research Laboratories Division and of colleagues in the Cadillac Engineering Laboratory who provided the data on which this paper is based.

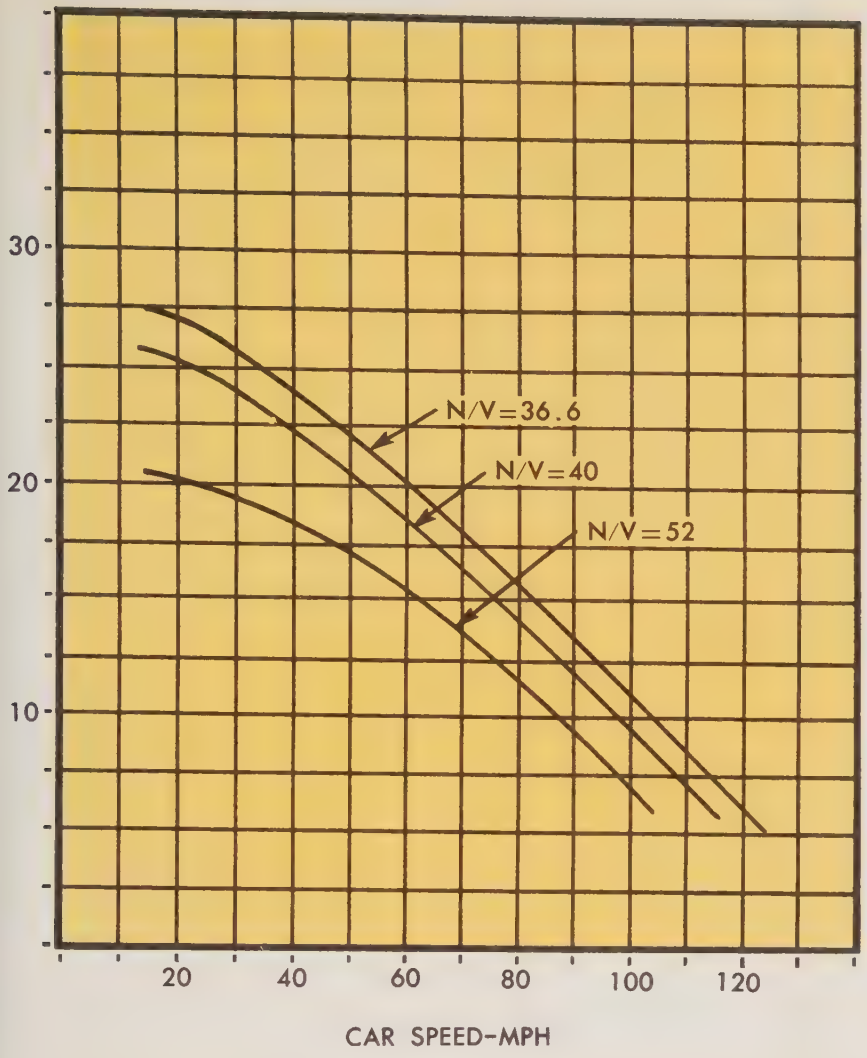


Fig. 8—Curves showing the effect of N/V ratio (engine rpm/vehicle speed) on road fuel economy of 1953 Cadillac with different rear-axle ratios. The 36.6 N/V ratio is standard on 1953 production Cadillacs.

On the other hand, the wedge-type turbulent chamber was free of objectionable combustion roughness when run at compression ratios of 9:1 with present-day premium fuel (92 Research Octane Number) and 12:1 with high octane fuel.

Conclusion

To give good economy and high output, an engine must be high in each of the basic efficiencies—volumetric, mechanical, and thermal.

How to attain high output and efficiency has long been known and practiced, as shown in engines for aircraft and racing vehicles—but to attain this power smoothly is the problem in the modern, high-performance car.

Comparative tests between the hemispherical, non-turbulent, and the wedge-type, high-turbulent combustion-chamber designs have shown that, while the hemispherical type is unquestionably good for brute power, it cannot—even with what turbulence can be added—compare with the wedge type in smoothness for fine passenger car use.

Roughness appears in the hemispherical combustion chamber when attempts are made to raise the compression ratio to take advantage of better fuels or to increase efficiency and economy. Roughness also becomes evident when the hemispherical chamber is used with tightly-coupled, efficient automatic transmissions necessary for best performance and economy.

Outputs of 250 hp are possible from present size engines with either the hemispherical or the wedge-type chambers. More than 250 hp does not appear to be a requisite for passenger cars.

The big difference in power smoothness is in combustion control—the wedge type produces its power smoothly, the hemispherical type with roughness. Where smoothness is not important, the hermispherical combustion chamber may be used, but for optimum passenger comfort, the wedge-type chamber with its high turbulence is the logical choice for smooth power.

Bibliography

Other related literature in this field includes the following:

Fry, A. S., Stone, J., and Withrow, L., "Analysis of a Shock-Excited Transient Vibration Associated with Combustion Roughness," *S. A. E. Quarterly Transactions*, Vol. 1, No. 1 (January 1947), pp. 164-184.

Garner, F. H., "Combustion Processes in Engines," *Journal of the Institute of Fuel*, Vol. 25, No. 142 (March 1952), pp. 42-9.

Geschelin, J., "Latest Advances in Combustion Chamber Design," *Automotive Industries*, Vol. 108, No. 9 (May 1, 1953), p. 54.

McCuen, C. L., "Economic Relationships of Engine-Fuel Research," *S. A. E. Quarterly Transactions*, Vol. 6, No. 2 (April 1952), pp. 290-303.

Rifkin, E. B., Walcutt, C., and Betke, G. W., Jr., "Early Combustion Reactions in Engine Operation," *S. A. E. Transactions*, Vol. 6, No. 3 (July 1952), pp. 473-87, 508-10.

Roensch, M. M., "High Compression Engine Performance," *Journal of Society of Automotive Engineers*, Vol. 57, No. 6 (June 1949), pp. 17-21.

Withrow, L. and Fry, A. S., "Physical Characteristics of Roughness in Internal-Combustion Engines," *S. A. E. Journal (Transactions)*, Vol. 52, No. 3 (March 1944), pp. 100-112.

Fraas, A. P., *Combustion Engines*, (New York: McGraw-Hill Book Company, Inc., 1948), pp. 75-122.

Taylor, C. F. and Taylor, E. S., *The Internal Combustion Engine*, (Scranton: International Textbook Company, 1948; 2nd Edition), pp. 102-27.

A Design Study: Planning Maximum Storage and Shipping Ease and Economy into Commercial Vehicle Bodies

By W. WALTER BERGER
Chevrolet Motor Division

Modern styling must satisfy many requirements to evolve good design in automotive products. Commercial vehicle design, in particular, is influenced not only by utility and appearance but also by the need to establish good shipping characteristics. Before finalizing all designs, Chevrolet engineers attempt to minimize the shipping and storage problems which increase the product sales price without giving a corresponding increase in value.

Proper parts nesting large factor in cost reduction

THE transportation system may be thought of as an extension of a plant's conveyor system. One of the most important aspects of commercial vehicle production is getting the material to its destination at the proper time, at the least cost, and in the best possible condition. In order to achieve this purpose, designers of commercial vehicles, especially, consider shipping, storage, and handling problems. Efficient utilization of storage area and transportation facilities for commercial vehicle body components and other parts is especially difficult because so many of them are large and bulky.

In the Chevrolet organization, assembly plants are set up at the point of consumption mainly to eliminate long hauls of finished completely assembled bodies. If undue damage and high shipping costs occur in the transporting of commercial parts, this purpose will be defeated.

Making Maximum Use of Storage Facilities

With plant-building costs on an upward trend, every square foot of plant area used for storage purposes becomes more costly than ever. Because the yearly volume of commercial vehicles is lower than passenger cars, production of all models is not on a continuous basis. Besides such factors as scheduling and design, the period of storage becomes especially important in handling the anticipated requirements of truck production. In the case of Chevrolet Motor Division, all commercial vehicle bodies are both fabricated and assembled by Chevrolet, as are commercial fenders, hoods, and grilles. At the fabrication plant, parts either are stored in the plant for future assembly, placed on or near the assembly line, or sent to the shipping area. Individual body parts and panels for the panel-truck, carryall, and canopy-express bodies which are stored for future use occupy the largest area. At the assembly plants, parts and sub-assemblies are stored near the freight unloading point or near the assembly line for immediate use.

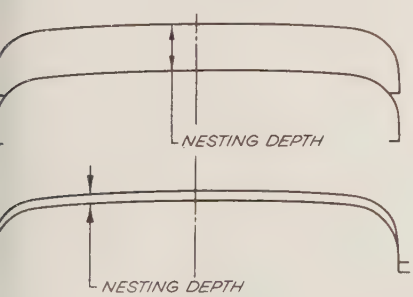
Storage racks are used in both the fabrication and assembly plants, making

Fig. 1—Geographical location of the 11 Chevrolet assembly plants in relation to the Indianapolis Fabrication Plant.

possible to tier four or five rows of aterial. These not only save space and rovide protection of parts but also ermit more efficient and safer material andling. Special temporary storage racks re required to protect prime-painted arts. The overhead monorail conveyor so may be regarded as a storage method nce body parts are hung from hooks or upporting fixtures at a starting point nd not removed until required—even hough the starting point may have een passed a number of times.

Another, and generally more costly, ethod of storage may result from leav- g parts in the freight cars at their desti- ation. This use of freight cars is penal- ed by the railroads, however, with a ostly demurrage fee for every day the ar remains on the plant siding after 8 hours.

In the manufacture of commercial ehicles, it is necessary to store vast uantities of parts. The resulting prob- em has been alleviated to some extent n Chevrolet by designing the various nodels with parts interchangeable where- ver possible. For example, all unit odies of the ½-ton 116-in. wheelbase roup use the same top panel (the small anel truck, the suburban-carryall, and ne canopy-express). In addition, the ame side door is used for all model rucks, unit and cab, with the exception f the cab-over-engine, or *C.O.E.* truck. Another example of interchangeability that all trucks with cabs, from the ½-ton light truck to the two-ton heavy ruck, have the same cab with the excep- ion of C.O.E. trucks. However, the C.O.E. truck cabs do make use of a num- er of the same panels as conventional abs. The cowl and dash assembly used n all models, unit and cab (with the xception of C.O.E. trucks), are also nterchangeable. If these had not been esigned as interchangeable panels, stor- ge costs, as well as manufacturing costs,



ig. 2—Nesting improvement achieved with anged-out construction as compared with anged-in construction.

TRUCK BODY DESIGNER'S CHECK LIST

Consider avoiding these characteristics:

- Projecting sections
- Flanges, especially constructions flanged inward
- Closed-box configurations which cannot nest favorably
- Sharp corners
- Any sharp changes in contour.

Try for these characteristics:

- Maximum interchangeability of parts
- Contact between nested parts along their entire surface
- If flanges are necessary in a construction having an included angle, the angle should be more than 90° by an amount to achieve optimum nesting.
- Shallow-drawn panels of simple contour
- Contour changes as gradual as possible.

Table I—A great number of factors go into optimum design of any component. Listed are some of the factors which designers consider in the development of parts for commercial vehicle bodies. The same list could apply to almost any large, mass-produced structures in which maximum shipping ease and economy are desired.

would have been increased. Storage problems become especially complicated by designs with flanged and curved surfaces, if these parts leave undue air space between stored parts.

Shipment of Commercial Vehicle Body Parts

All Chevrolet commercial body parts and some sub-assemblies are fabricated at a plant in Indianapolis. From this fabrication point, parts are shipped by rail to 11 assembly plants elsewhere (Fig. 1). The Indianapolis plant ships out bodies in a partial or completely knocked down state only. Assembly takes place at the other plants.

The Designer and Freight and Storage Factors

In such a case, where fabrication and assembly points may be far apart, engineers give serious thought to designing for the most favorable return from avail-

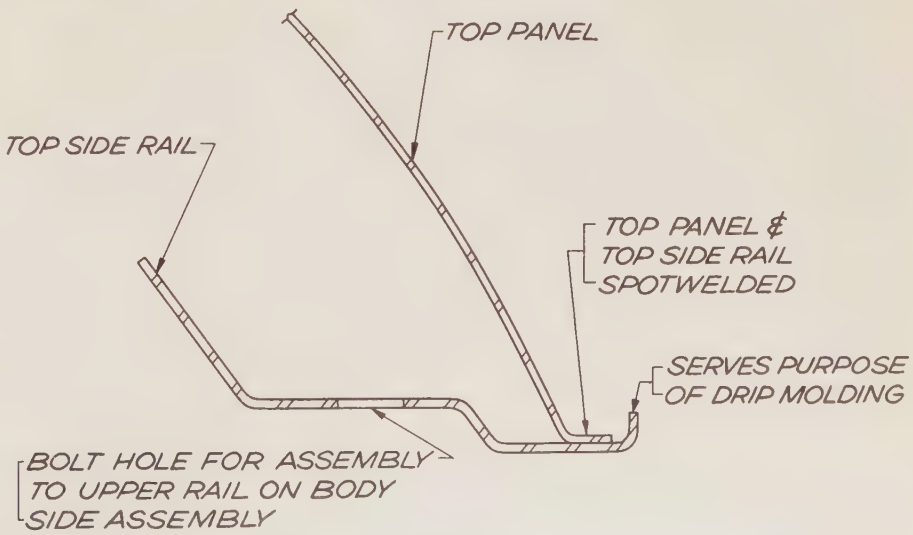

TOP PANEL
TOP SIDE RAIL
TOP PANEL & TOP SIDE RAIL SPOTWELDED
SERVES PURPOSE OF DRIP MOLDING
BOLT HOLE FOR ASSEMBLY TO UPPER RAIL ON BODY SIDE ASSEMBLY

Fig. 3—A good example of flanged-out construction is shown here on the panel-body top assembly. When assembled, the top side rail is spotwelded to the top panel along the flange and also is formed to act as the drip molding.

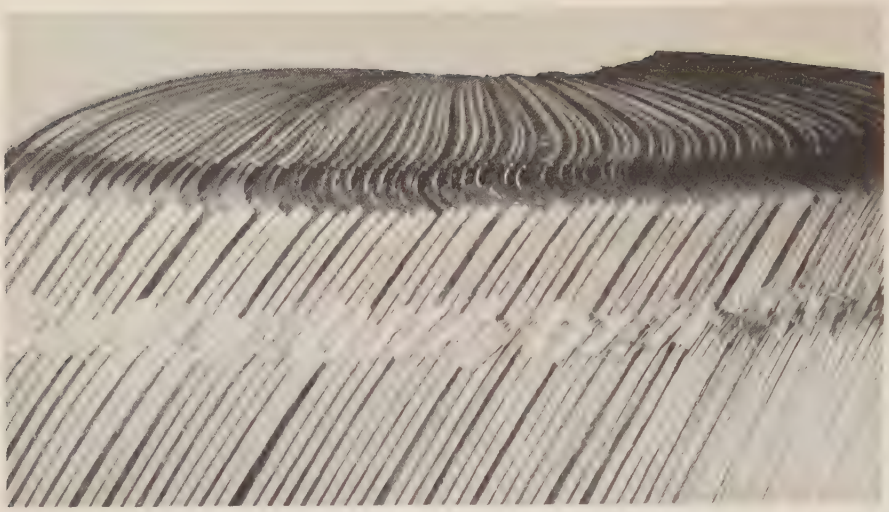


Fig. 4—Panel truck sides nested in storage. These panels use flanged-in construction where the width of the flange is narrow enough to permit good nesting.

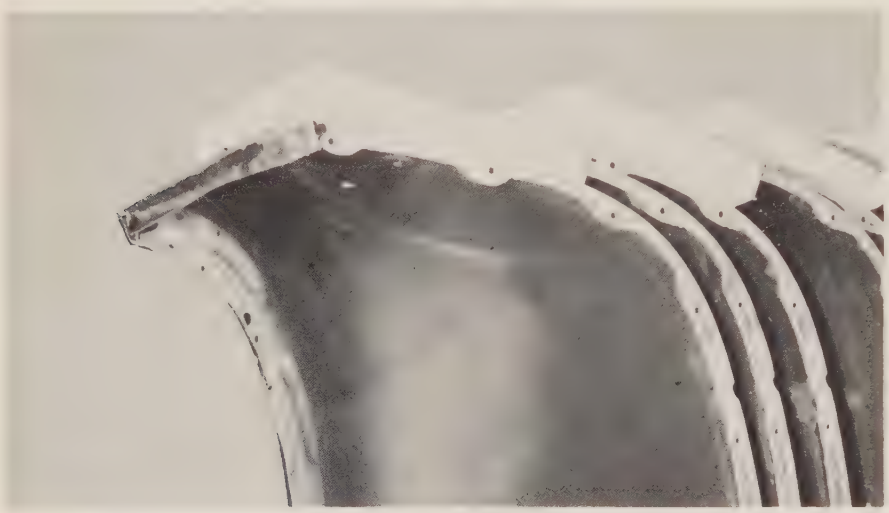


Fig. 5—Width variance in the forward hood flange before correction. The extreme corner of the flange tended to cut through protecting material in shipment and creased the nose of the next hood panel.

able storage and shipping facilities. Even the rates and rules and regulations of freight carriers are of importance to the engineer.

Freight carriers publish what is known as a *Freight Classification* for the purpose of designating an article as belonging to a certain class of goods. Each class consists of a group of articles with like transportation characteristics. After the class of a particular article has been determined, the transportation rate then can be ascertained from the freight carriers' published freight rate tariff. Where goods are shipped regularly and in volume they may be entitled to a lower classification and rate. In such instances, the freight carriers may accomplish this by publishing exceptions to the freight classification, or a special commodity rate. All such tariff publications are subject to regulation by the Interstate Commerce Commission for interstate traffic, and the various state regulatory bodies for intrastate traffic.

Most automotive body assembly material is shipped under exceptions to the freight classification or at special commodity rates. However, in order to get the benefit of lower freight rates allowed under the *Exceptions* or *Commodity* tariffs, a specified minimum weight for each freight car must be observed. Failure to make these minimum weights results in higher freight charges per unit shipped. For example, if the carload minimum weight on a particular article shipped is 30,000 lb and the actual weight of the shipment is 25,000 lb, then freight charges would be paid on the 5,000 lb deficit in weight. (Paying for a small deficit, however, may result in an advantage of a lower total freight charg than if the same goods were shipped a the higher, less-than-carload rates.)

Reduction in the amount whicl cars are *light loaded* is vitally importan in a large scale activity such as th Chevrolet organization's commercial ve hicle operation. An average of 42 freigh carloads may be shipped daily fron Indianapolis to the 11 assembly plants If each of these cars were light loade 5,000 lb, the total light load per da would be 210,000 lb—or about 27,30 tons per year which would be paid fo but not shipped. Light loading is reduce to some extent by improved loadin procedure. Improvement in design als helps to lower rates by enabling part to be shipped knocked down and with better nesting qualities (Table I)—elim inating damage and special handling.

The term *nesting*, when applied to th storage and shipment of sheet meta body parts, refers to identical adjacen parts which overlap or are closely mated A body part which nests well is usuall one with a simple shape and which fit along the contour of the adjacent part with a minimum of air space betwee complex curved contours often caus nesting difficulties, especially if the chan in contour is rapid. The nesting chara teristics of a part or sub-assembly a affected by the original design of th body and its components, the locatio and number of panel joint lines, and th amount of sub-assembly work which ha been done prior to shipment or storag In the design of body parts, a *balan point* is sought between the extra strengt obtained on deep-drawn, high-crow panels and lower shipping costs on fla shallow-drawn panels.

Flanges on body parts, while necessar for assembly and additional strength cause trouble in nesting. In the assembl of two flanged panels, conventional spo welding guns are used to weld th adjoining flanges. This type of flanging especially troublesome when done o opposite sides on the part. The flange being turned inward give the effect of closed-box shape and make nesting ex tremely difficult. By turning the flange outward instead of inward, nesting ca be improved (Fig. 2).

This type of *flanged-out* construction sometimes used on panels which ar hidden or where the joint can be covere by some type of molding. A good exam ple is on the panel-body top assembl

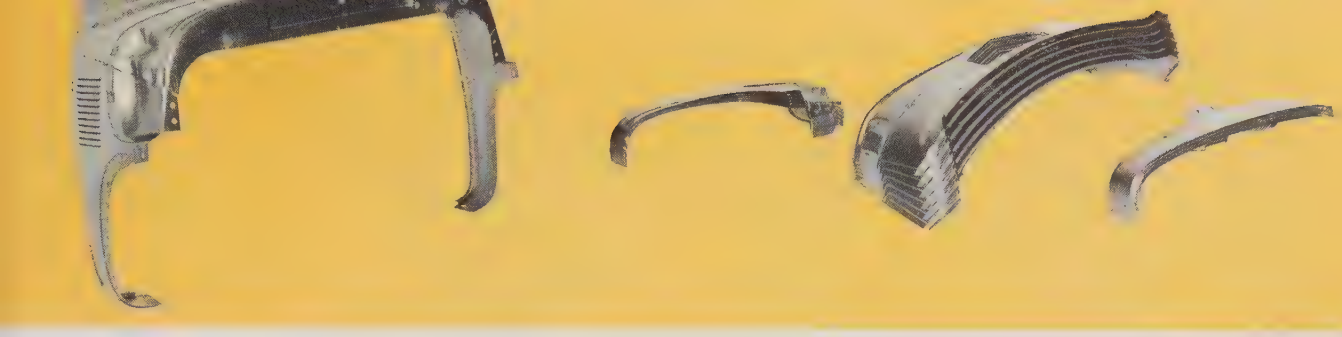


Fig. 6—Left, complete cowl-panel assembly and, right, the cowl panel broken down into cowl top panels and side panels for ease of fabrication and shipment.

here the top side rail is spotwelded to e top panel along the flange and is so formed to act as the drip molding ig. 3).

A flange turned inward from a rela- vely flat panel does not give much ouble since the width of the flange is ually from ½ to 1 in., and even if the rts do not nest well, the distance be- een the panels is not great. The hevrolet panel-truck side panels are nged in this manner yet still nest well storage (Fig. 4).

Since flanges on body panels are evitable, consideration is given in de- gning the part to make possible an otimum degree of nesting. Flanges may e placed along two adjoining edges thout interference. The width is also nportant, since ¼ in. may make a fference of several inches in the dis- nce between nested parts. Where anges cannot be designed with a uni- rm width, engineers seek to make the idth variance as gradual as possible. An example of adverse width variance, ow corrected, is shown in Fig. 5. Here e variation was due to a trim die con- tion and caused shipping damage. In ipment, the extreme corner of the ange had a marked tendency to cut rough the protecting cardboard and eased the nose of the next hood panel. hese needed to be repaired, of course, uring the manufacturing procedure.

Body parts also nest better if the indi- dual parts are made smaller; that is, the body is divided into more parts uring the design phase. A balance point sought between decreased shipping xpense by making the body in more ctions and the additional cost of manu- cturing to assemble the body. If fewer anel joints are made, freight costs tend increase and assembly costs generally ecrease. Stock size and fabrication pro- edure also are important. Sheet metal ock of un-standard size sells at a remium rate. If the panel happens to e large, it may be made in two parts.

Some panels are difficult to fabricate because of shape or size, in which case, the part may be broken down into several sections. The cab-cowl outer panel is broken down into the top and the two sides for ease of fabrication (Fig. 6). As an additional benefit, this break-down gives better nesting qualities.

Weight-to-Bulk Ratio Considerations

Since formed body parts occupy a large volume but are relatively light in weight, the ratio of the weight to the bulk or the volume occupied is a convenient method of spotting parts which may cause increased shipping and storage costs. The *weight-to-bulk ratio* is determined mathematically by dividing the weight of a part by the volume it occupies. A part with a low weight-to-bulk ratio invariably has higher than normal shipping cost per pound. The effective volume of a part may vary due to tightness of nesting, angle or springing of the part, or the need for protective cardboard. The space gain from nesting is very large in some cases and almost always worthy of considerable design attention (Table II). Nesting even of the bulky C.O.E. cowl and dash offers some gain in weight-to-bulk ratio. The back panel strainer has a good initial weight-to-bulk ratio but the *ratio is increased 18 times by nesting.*

Loading and Unloading Factors

Another factor which is not neglected in the Chevrolet Engineering Department is the labor requirement for loading and unloading freight cars used to transport parts from Indianapolis to the assembly plants. When materials can be easily handled by laborers working by hand or with machinery, the unit cost per vehicle assignable from the Materials Handling Department is kept at a low level. Both loading and unloading are affected

Body outer lower panel	25.0	11.90	3.96	2.10	6.32
Body outer upper panel	38.0	34.40	5.98	1.15	6.35
Front fender (truck)	21.98	24.78	6.31	0.89	3.48
Dash and toe pan	15.8	4.23	0.56	3.73	28.20
C.O.E. cowl and dash	75.6	71.20	52.90	1.06	1.43
Floor pan and seat riser	64.0	18.82	10.89	3.40	5.88
Side door	36.3	6.55	5.05	5.55	7.20
Cowl top panel	11.1	6.15	0.75	1.81	14.80
Body back panel strainer	1.3	0.18	0.01	7.23	130.0
Top assembly (3105)	122.5	55.4	19.5	2.21	6.29
Side assembly (3105)	122.5	31.3	16.5	3.92	7.43

Table II—Many gains in obtaining maximum ease and economy of storage and shipping result when designers take into account nesting considerations. Computations such as shown here point out the parts on which nesting improvements may be sought in later models.

Fig. 7—Left, nested assemblies consisting of cowl top panels and ventilator gutter assemblies and, right, cowl top panels and gutter assemblies not assembled. Note the greater space occupied by the assemblies at the left due to projecting gutter assembly while both of these parts can be nested better by shipping separately as shown at right.

equally by the basic decisions made months or years earlier on the drawing board.

Small parts are handled in bins, barrels, crates, sacks, or wired together. The great number of small parts which can be handled as a unit do not prove troublesome since the Materials Handling Department has appropriate equipment for their movement. Larger components, such as panel-truck side and top assemblies, are given more design attention because these units need to be handled one at a time.

Sub-assembly Operation at the Eleven Assembly Plants

A body may be shipped completely knocked down *C.K.D.* as individual parts, or completely assembled at the plant where the parts are fabricated, and then shipped as a complete body. Between these two extremes are various stages of partial assembly. If sub-assembly operations can be performed at the assembly plants, then parts can be shipped separately, resulting in savings in shipping costs. Unfortunately, these savings can only be realized if tool costs are low enough to justify doing this work at an assembly plant. All truck hoods are shipped in two sections for improved shipping qualities and then riveted at the plant. If possible, the parts of the sub-assembly are designed so the assembly work can be done with conventional electric or gas welding equipment.

The same equipment can then be used on several similar operations. Any sub-assembling operations which require welding presses on low production parts usually are sub-assembled and then shipped to the assembly plants. Panel bodies are shipped partially knocked down into nine sub-assemblies and the cowl is shipped completely knocked down.

Sub-assembling after shipment is applicable especially to brackets and other projecting small parts welded to a main part to make up a sub-assembly. Brackets are generally welded to the surface of the main part and project at sharp angles to this surface (Fig. 7). This means the parts cannot be nested closer together than the distance the bracket projects.

Sometimes, if a part or bracket having an uncritical location is to be added, it is located by a depression, shoulder, or hole in the main part. This reduces tooling cost by eliminating a locating fixture.

In addition to welding, bodies are also assembled by bolting and riveting. These methods of body assembly generally are more expensive per unit than welded construction but they largely eliminate the need for assembly fixtures since parts are located by pre-punched holes. Threaded fasteners and rivets are, therefore, the ideal method for low production assembly because of the low tool cost. The assembly cost is the same whether done at the assembly or fabrication plant. Fig. 8 shows the riveting of a reinforcement in the C.O.E. hood at the assembly plant. Shipping this assembly knocked down requires only one-third of the space needed for assembled shipping.

Holding Shipping Damage at Minimum

The problem of shipping damage is another area which the Chevrolet Engineering Department considers in finalizing its designs. Special attention is devoted to sheet metal fabrications. Sheet metal body parts are usually 0.030 to 0.040 in. thick and may be formed into complex shapes with perhaps projecting sections and sharp corners which, when nested, might damage adjacent parts. Body parts are susceptible to damage which must be repaired during the as sembly operations. In the shipment o body parts from Indianapolis, finish an paint scratches are not a problem. A parts are shipped unpainted except th unit-body panel assemblies which ar prime-painted. Any paint scratches whic occur are covered by retouching th prime coat and by the finished color coa

The cost of repair operations on damaged part is dependent on the typ and extent of damage. Dents woul require a bumping and metal-finishin operation. Distorted sections and ben flanges would require straightening oper ations, while torn and punctured par would require a welding operation i addition to metal finishing. Damage parts are often run down a repair li but slight defects such as flanges an small dents are most often repaired o the assembly line. In either case, the co of the part is increased due to the ex labor expended on it.

The hood assembly in Fig. 9 has hinge reinforcement welded into th hood panel. This projecting reinforce ment previously was sharp and cause nesting damage to adjacent parts. Th condition was eliminated by roundin off the projections. The cause of most o the damage to body parts can be trace back to design features on adjacent part Sometimes, a jar of the boxcar while i transit causes damage but this is prac tically unavoidable. Parts which are con tinually damaged under *normal* operatio are strengthened at the weak spo if possible.

Sharp corners or intersections of su faces exert a localized load on an adja cent part if two parts contact at tha point while large radius corners have les tendency to cause surface dents. If poss ble, flanges on parts are designed to b of a uniform width along the entir length of the flange. Parts are designe with as few projecting sections as possibl

A projecting section which is the only ontact on the next part causes the entire eight of all above parts or the force of arts shifting in transit to be concentrated t that one point. Parts which are to be ested are designed, therefore, to have as uch metal-to-metal contact between djoining surfaces as possible.

Discussion

Since trucks are not produced on a ontinuous production basis, a long stor-ge period makes it imperative to reduce torage space occupied by commercial ehicle body parts. Low inventories on roduction panels must be replenished eriodically and stored until needed. y re-designing new models to have parts nterchangeable with models already stablished, the number of body parts in torage is reduced considerably.

In shipping body parts or assemblies, roblems are more critical on account of he fact that shipping costs are higher han storage costs, and conditions in ransit are more conducive to damage. very effort is made to load the freight ar to the required minimum carload eight which gives the least cost per ound of shipped material. This can be ccomplished by designing all parts to est well.

Damage can be reduced by protective easures such as the use of lumber and ardboard. However, the method is xpensive in itself not only because of the aterial and labor costs involved but so because such protective material ccupies space and adds weight, thus creasing the shipping costs.

Damage is further reduced by design-g the parts to be damage resistant and ondamaging to neighboring parts.

In loading or unloading of parts, anual labor is the most costly item. fficient handling is affected by the bulk nd weight of parts, the extra labor and aterial required to apply protective material around easily damaged parts, and the delay caused by the extra care with which such parts must be treated.

A large part of the answer in achieving maximum ease and economy in shipping and storage of body parts lies in proper nesting. Parts which are nested well are closely mated with a minimum of air space between. The design of a part is the dominant factor in determining how well it nests. If a body part has design features which are necessary for its construction or appearance yet cause it to nest poorly, a compromise can often be reached between the desired features and improved shipping characteristics. A balance point must be reached at which both shipping and assembly costs are moderate.

Savings in shipping costs are also achieved by sub-assembling at the assembly plant. Whether or not this is done is determined by relative tooling and shipping costs.

Conclusion

In the design of the body and its component parts lies the most effective method of reducing or eliminating the problems which exist in the shipping, storage, and handling of parts. However, because a part ships poorly does not necessarily mean that it should be re-designed. There are other factors which must be considered, such as its utility and appearance, the costs of manufacturing, assembling, and tooling, and the extent of yearly production.

Acknowledgement

Appreciative acknowledgement for sistance during the preparation of this aper is made especially to Mr. E. J. remo, assistant chief engineer, Chevro-t; to Mr. E. C. Mertz, truck body engi-eer, Chevrolet—Indianapolis; to Mr. E. McGee, superintendent of Material andling, Chevrolet—Indianapolis; and Mr. E. B. Hurst, General Motors stitute Staff.

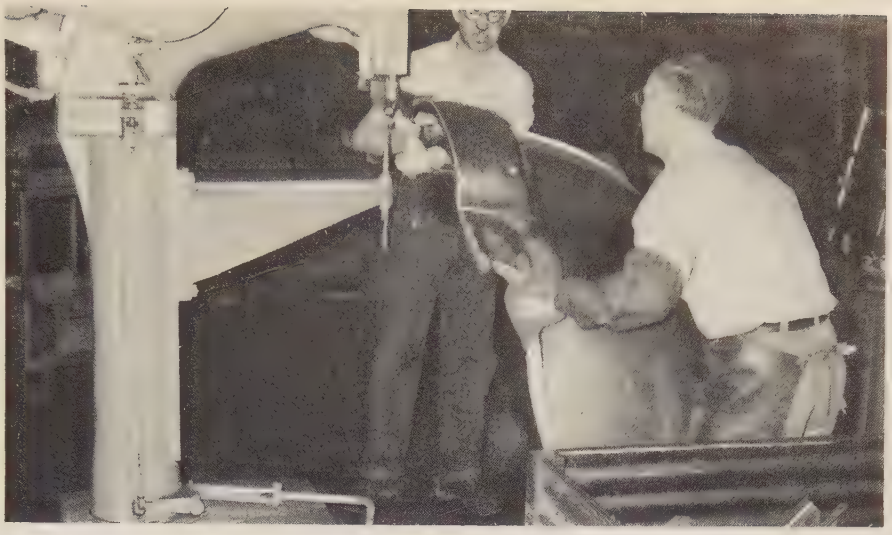


Fig. 8—Riveting a reinforcement in the C.O.E. hood, a typical sub-assembly operation at one of the assembly plants.

Fig. 9—Projecting corner of hinge reinforcement welded in the hood assembly. This bend, formerly much sharper, was rounded off to minimize damage which previously occurred in shipment.

The Buick Air Power Carburetor

By ADOLPH F. BRAUN
Buick Motor Division

New design brings greater power output plus fuel economy

Carburetors and carburetor design promise to remain important phases of automotive engineering as long as the automobile internal-combustion engine uses liquid gasoline as fuel. No automotive power plant yet has proven prepared to replace the spark-ignition system. The automobile carburetor is commissioned the job of regulating the fuel-air ratio that is sent to the engine. The ideal carburetor has the characteristics of ease of starting, clean pickup, maximum power with minimum fuel consumption, comparative degree of silence when in use, ease of adjustment, a minimum of moving parts, and general simplicity of construction and detail. With these aims in mind, the engineers at Buick Motor Division developed the Air Power Carburetor, designed to increase engine power output at high speeds while still assuring greater fuel economy, especially at low and moderate speeds.

THE automobile carburetor is assigned the task of converting raw fuel into a spray of vapor, mixing the vapor with air, and sending the gasoline-air mixture to the engine. The gasoline-air ratio in present-day automobiles varies from 6 lb of gasoline per 100 lb of air to about 12.5 lb of gasoline per 100 lb of air. The richer mixtures, starting around 9 lb of fuel to 100 lb of air, are needed for automobile starting, warm up, and accelerating. The leaner mixtures are best when the car is running at a constant speed. As a general rule, rich mixtures produce higher power while lean mixtures give higher economy. It is the difficult task of the engineer to design carburetors that will deliver the correct fuel-air ratio to the engine—regardless of the load, climatic conditions, speed, and variations in fuel.

The Air Power Carburetor

The Buick Air Power Carburetor, introduced on the 1952 Roadmaster, is modeled after the concentric-bowl type carburetor used on Buicks for many years. Basically, the new unit consists of two dual carburetors mounted back-to-back. New intake and exhaust manifolds have been designed for use with this carburetor.

Primarily, the Air Power Carburetor is designed to increase the power output of the engine at high speeds and, at the same time, to give better fuel economy, especially at low and moderate speeds. Greater power is obtained through reduced carburetor restriction and improved volumetric efficiency which permits delivery of more fuel-air mixture to the combustion chambers at high speeds. Also, the primary carburetor is smaller than a conventional dual carburetor for the same engine. This provides higher air velocities through the carburetor which, in turn, permit more accurate metering for better economy.

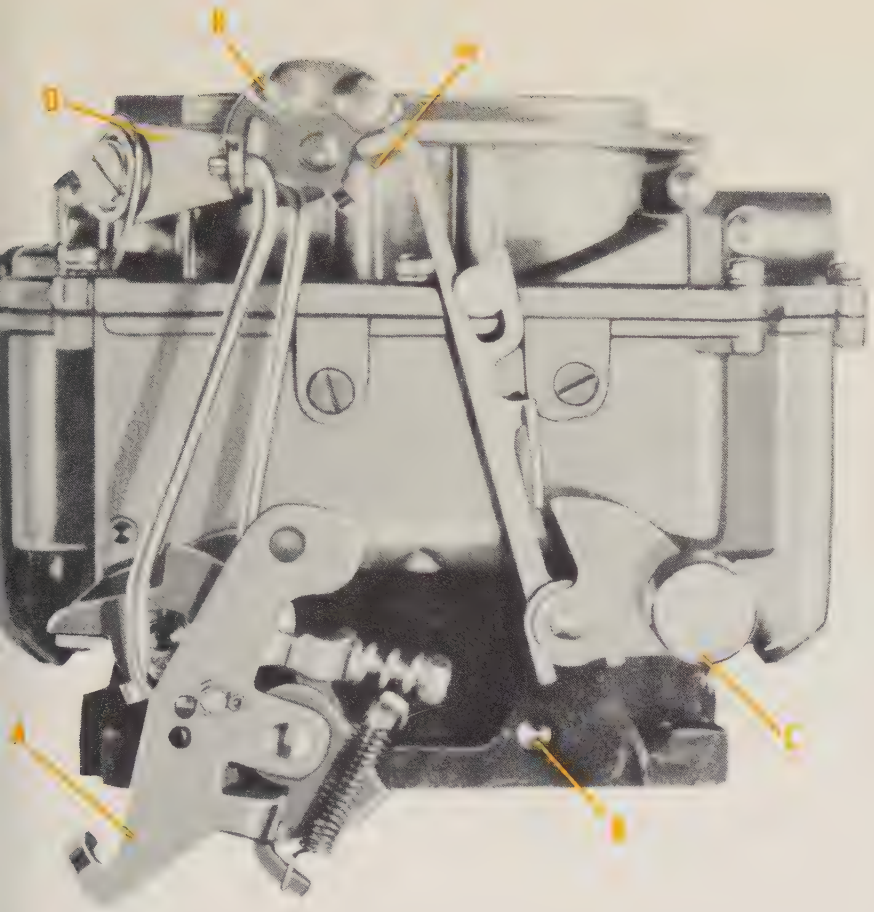
About the same power output at high speeds could be obtained with a larger dual carburetor. However, the larger unit would be too large at low-engine speeds and would actually cause a loss in power under those conditions. In the Air Power Carburetor, the primary part may be tailored to fit the engine requirements at lower speeds and, with the auxiliary throttle valve, the secondary carburetor may be cut in as necessary. This gives nearly ideal results for maximum power output throughout the engine speed range.

All the essential parts normally used in carburetors are found in the primary or front carburetor including: an idle system with mixture quality and speed adjustments, a main metering system with a vacuum-controlled enrichment device for full-throttle power, automatic choke, fast idle control, a port for actuating the vacuum advance of the distributor, a throttle lever, accelerating pump, and a starter switch. The secondary or rear carburetor has only a non-adjustable idle system and a main metering system calibrated for wide-open throttle operation. In the secondary unit, the throttle is operated from the primary throttle lever by a link and pick-up lever.

During part-throttle operation, in the normal range of cruising speeds, the fuel and air supply is metered by the primary carburetor only. The accelerator pedal is connected to the primary throttle lever of the carburetor. When the primary throttle is about one-half open, at maximum cruising speed, a pick-up lever engages a loose lever on the shaft and by means of a link and lever starts to open the secondary carburetor. Geometry of the linkage is such that the opening rate of the secondary carburetor is about twice that of the primary so that, when the primary is wide open, the secondary also is wide open. The reason for having a metering system only in the secondary carburetor which will deliver a full power mixture is that, when high speeds are desired, it is not possible to run on the lean mixture used at the lower speeds. At high speeds, the primary carburetor also delivers the richer mixture required for full power.

Above the main throttle valve in the secondary carburetor is an auxiliary throttle valve. It is an unbalanced valve held shut by means of a weighted lever and its function is to control the air and fuel flow through the secondary carburetor according to engine requirements rather than throttle position. When the manifold depression becomes great enough at wide-open throttle, the auxiliary valve opens and the secondary carburetor begins to function.

By placing the auxiliary throttle above the main secondary throttle, it is in a



g. 1—Outside view of the left side of the four-barrel carburetor as installed on the Buick. *A* is a lever ached to the throttle shaft of the primary carburetor. *B* is the protruding end of the throttle shaft in secondary carburetor. These throttles reach the wide-open position simultaneously since the secondary ottle opens at approximately twice the rate of the primary throttle. *C* is the auxiliary throttle valve, s the lever which actuates the acceleration pump, *K* is the linkage on which is located a fast idle cam, s a vent tube.

w-suction location and does not in-ease the leakage into the manifold. ny leakage through its bearings still has pass the main throttle valve.

terior Mechanical Details

Fig. 1 shows the left side of the four-rrel carburetor as installed on the tomobile. Lever *A* is attached to the rottle shaft of the primary carburetor d is actuated through the throttle ntrol linkage by the accelerator pedal the car.

Shaft *B* is the protruding end of the rottle shaft in the secondary carbure-r. The secondary throttle is operated the primary throttle through a loose er and pick-up linkage located on the ht-hand side. The linkage is adjusted that the secondary throttle starts to en when the primary throttle reaches e half-open position. However, the ondary throttle opens at approximately twice the rate of the primary throttle. Thus, the throttles reach the wide-open position simultaneously.

Lever *C* is a weighted lever serving as a counterweight for an offset valve located in the secondary carburetor directly above the throttle valve. (This assembly is referred to as the auxiliary throttle valve in the remainder of this paper.)

Lever *D* is the part of the mechanism which actuates the acceleration pump. This pump is, for all practical purposes, the same in construction and principle of operation as the one in Buick's previous dual carburetor. The acceleration pump is operated by the primary throttle lever *A* and supplies a jet of liquid gasoline for mixture enrichment on sudden throttle openings to the primary carburetor only.

The Float System

Each unit of the carburetor has a separate float chamber with two interconnected floats actuating a float needle valve mounted in each chamber. These hold the fuel level at the nozzle outlets constant so that *flooding* or *leaning out* cannot occur on grades. One gasoline inlet feeds both chambers through a channel in the float chamber cover.

Fig. 2 shows a section taken through the left side of the carburetor on the approximate centerline through the *venturis*. A venturi is a restriction in the air passage through the carburetor to the engine. The air rushing through this restriction (when the car is traveling at 70 mph, the air hurtles through the venturi at the rate of 250 mph or more) creates a partial vacuum and forces the gasoline into the air stream in a fine spray where it is mixed with air in the correct ratio and delivered to the engine. The dotted line shows the fuel entering the carburetor at the gasoline connection, flowing through the needle valve *F* and into the primary float chamber. The fuel flows in a like manner through a cored passage (not shown) to the rear, and through the needle valve F_1 into the secondary float chamber. *E* shows the skeleton of one of the secondary dual floats attached to its hanger. E_1 is the sectioned float hanger which supports the left float of the primary carburetor. When the fuel reaches the prescribed level (dotted line) in the float chambers, the dual floats press the needle valves against their seats and cut off the flow of fuel. Thereafter, the fuel is maintained at the proper level in each carburetor by the opening and closing of the needle valves as required.

Location of the floats is such that the ascent or descent of a grade, resulting in a tilting of the fuel level, has little or no effect on the metering of fuel from the main nozzles *Y*, Y_1. Constant static lift at the nozzle outlet of both the primary and secondary units is maintained by the use of separate float chambers, and the location of the floats is such that a fore and aft centerline through the float would pass approximately through the nozzle outlet.

Venting

The float bowl of each unit is vented internally to its respective air horn through vent tubes *L* and L_1 (Fig. 2). A second vent tube *m* (Fig. 1) connects the innermost part of the air horn rim with the rear of the primary float chamber.

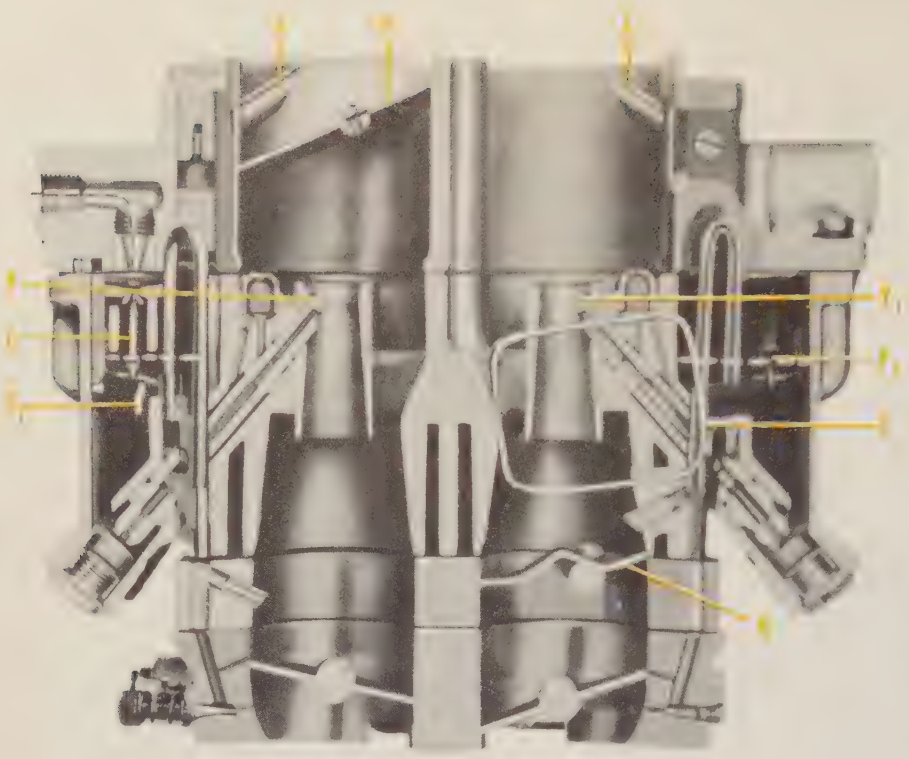


Fig. 2—Section through the left side of the carburetor on the approximate centerline through the venturis. The Air Power Carburetor is, basically, two carburetors mounted back-to-back. The dotted line, upper left, shows passage of the fuel entering the carburetor at the gasoline connection, flowing through the needle valve F and into the primary float chamber. Y, Y_1 are the main nozzles; E shows the skeleton of one of the secondary dual floats; E_1 is the sectioned float hanger which supports the left float of the primary carburetor; F_1 is a needle valve; L, L_1 are vent tubes; H is a choke valve; G is the auxiliary throttle valve.

The location of the vents as described, prevents both vents from being blanked off by the tilting fuel level as the car ascends or descends grades, undergoes sudden stops, or rounds curves at high speeds.

The air cleaner may be removed from the carburetor or a restriction added to the air inlet without changing the metering characteristics.

The Automatic Choke

An automatic choke is employed on the Air Power Carburetor which is similar in construction and operation and identical in principle to that used in Buick's previous dual unit. It is located in the primary carburetor and has a choke valve H in the primary air horn only (Fig. 2).

Fig. 2 shows the choke valve closed. A lock-out device is employed which holds the auxiliary throttle valve G in the closed position when the choke valve H is not fully open. The lock-out linkage does not release the auxiliary throttle valve until the choke valve reaches a nearly-full-open position (Fig. 3). Thus, the main discharge system of the secondary carburetor is rendered inoperative during the engine warm-up period when the choke valve is partially closed. Without this, the wide-open throttle operation during warm up would be very lean as no enriching device is provided on the secondary carburetor. An automatic choke cannot be used readily on the secondary unit unless the choke valve is partially opened by some means so that the depression at the nozzle is low enough to prevent it from feeding fuel until the secondary throttle starts to open. At best, the addition of an automatic choke on a secondary carburetor would be very expensive and add complications to the carburetor design.

A fast idle cam, located on the primary unit through linkage K (Fig. 1) is controlled by the automatic choke. Thus, during warm-up periods the engine operates at a higher idle rpm in exactly the same manner as it does when equipped with Buick's conventional carburetor.

The Idle System

Two separate idle systems are provided in the Air Power Carburetor. The principle of operation is the same in each and identical to that in a dual carburetor.

By having the primary and secondary throttles close together, it is possible to adjust the mixture quality at idle on the primary unit, with a fixed fuel discharge on the secondary, and still affect all cylinders on each manifold branch equally. This could not be done with the compound carburetor system.

Idle System in the Secondary Carburetor

An idle system used in the secondary carburetor delivers a portion of the fuel required when the engine idles. At high speeds, on part throttle, it assists in bringing in the secondary carburetor smoothly. No lean spot develops before its main metering system starts to function. At lower speeds, on part throttle, the idle system in the secondary also delivers nearly the same amount of fuel as it does at idle. This helps to maintain the correct fuel level in the secondary bowl by using fuel faster than the normal *creep* in level caused by vibration of the float mechanism. In the secondary unit the throttle valves close against the throttle bore wall reducing the air flow to a minimum. Angles on the throttle valves are such that they will not wedge and stick shut.

On this carburetor, the idle system used has a much lower minimum air flow than the compound carburetor system. This means that the engine idle speed can be maintained as low as the speeds Buick has been using without getting roughness and missing.

Internal Mechanical Design

Fig. 3 shows the carburetor with the engine fully warmed up and idling. Fuel is delivered to the engine through the idle system at closed throttle and light load speeds from 20 to 30 mph. When the throttles are closed and the engine assumes an idling speed, a high-vacuum area exists directly below the throttle valves. This high-vacuum area, transmitted to some extent through the idle discharge holes, causes a lowering of the pressure in the entire idle system. Fuel flows from the float chambers O, O through the main metering jets P, P_1 and upward through the U-shaped idle tube

M, M_1 which meter the fuel. As the fuel approaches the crest of the idle tube it is mixed with air from the idle-air bleeders N, N_1. The fuel-and-air mixture then flows down the opposite side of the idle tubes through the idle channels Q, Q_1 to the idle discharge holes S, S_1 and T, T_1. Additional air is drawn into the fuel-air mixture in the idle channels through the throttle body idle-air bleeders R, R_1. During closed-throttle idle operation, the mixture is drawn only from the lower-idle discharge holes T, T_1 due to high suction at these points. As the throttles I, J are opened, suction is also placed on the upper idle discharge holes S, S_1 which causes these holes to feed additional fuel.

Fuel supplied through the idle discharge holes diminishes as the throttle valves I, J are opened to the point where the main metering system begins to supply fuel until a throttle position is reached where the idle system ceases to function.

The idle needle valve U controls the quantity of fuel mixture that is supplied through the lower idle discharge hole T_1 of the primary carburetor, thereby affecting the final air-fuel ratio supplied to the engine while the idle system is in operation.

The quantity of fuel mixture that is supplied through the lower idle discharge hole T of the secondary carburetor is controlled solely by the size of the hole. Thus, this quantity remains constant during idle operation.

The Main Metering System

The main metering system of the primary unit controls the flow of fuel during the intermediate or part-throttle operation, starting at approximately 20 mph and continuing throughout the cruising speed range. This function in the Air Power Carburetor is identical to that of Buick's previous dual carburetor.

Air entering the barrel through the air horn V, Fig. 4, passes through the large and small venturi tubes X and W which increase the velocity of the air and create a suction on the main discharge nozzle Y. This causes fuel to flow from the float chamber through the main metering jet P_1 into the nozzle. Air is drawn through the high-speed bleeder Z so that a mixture of fuel and air is discharged from the nozzle into the air stream passing through the small venturi.

The nozzle is designed so that if any

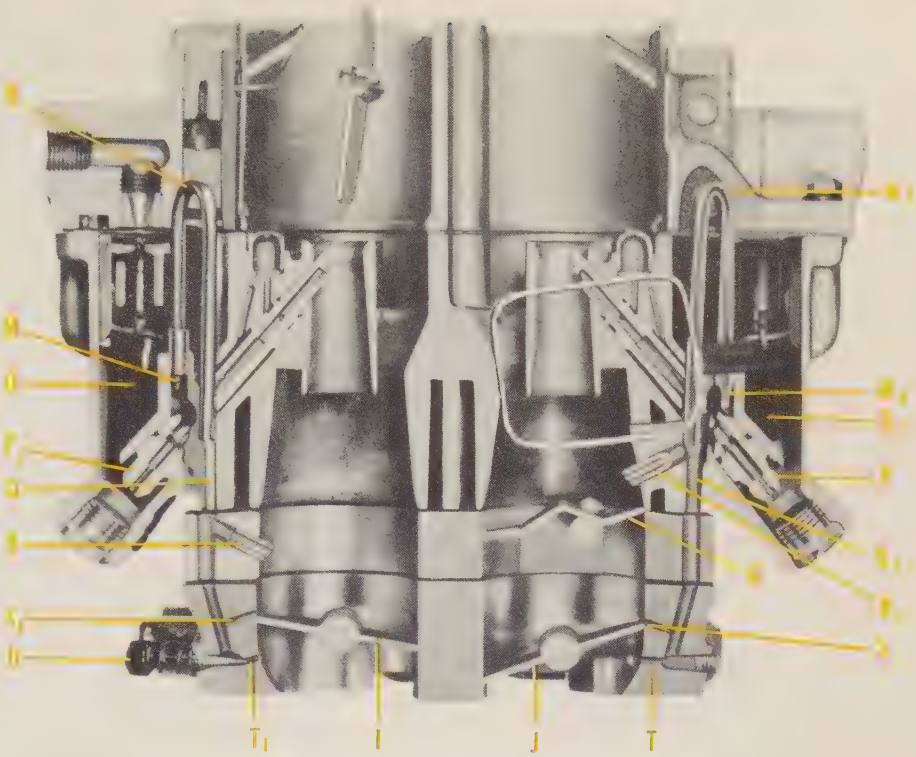


Fig. 3—Carburetor when the engine is fully warmed up and idling. N, N_1 are idle-air bleeders; M, M_1 are the U-shaped idle tubes; O, O_1 are float chambers; P, P_1 are main metering jets; Q, Q_1 are idle channels; R, R_1 are throttle body idle-air bleeders; S, S_1 and T, T_1 are idle discharge holes; I and J are throttles.

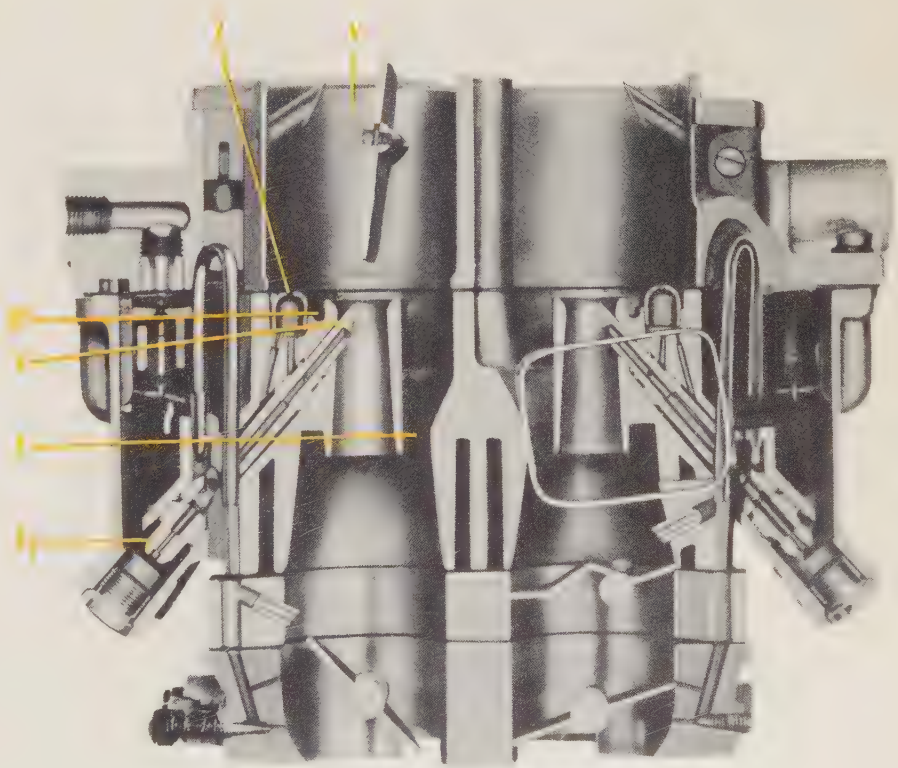


Fig. 4—Carburetor at part-throttle position. X and W are the large and small venturi tubes, respectively; Y is the main discharge nozzle; V is the air horn; Z is the high-speed bleeder.

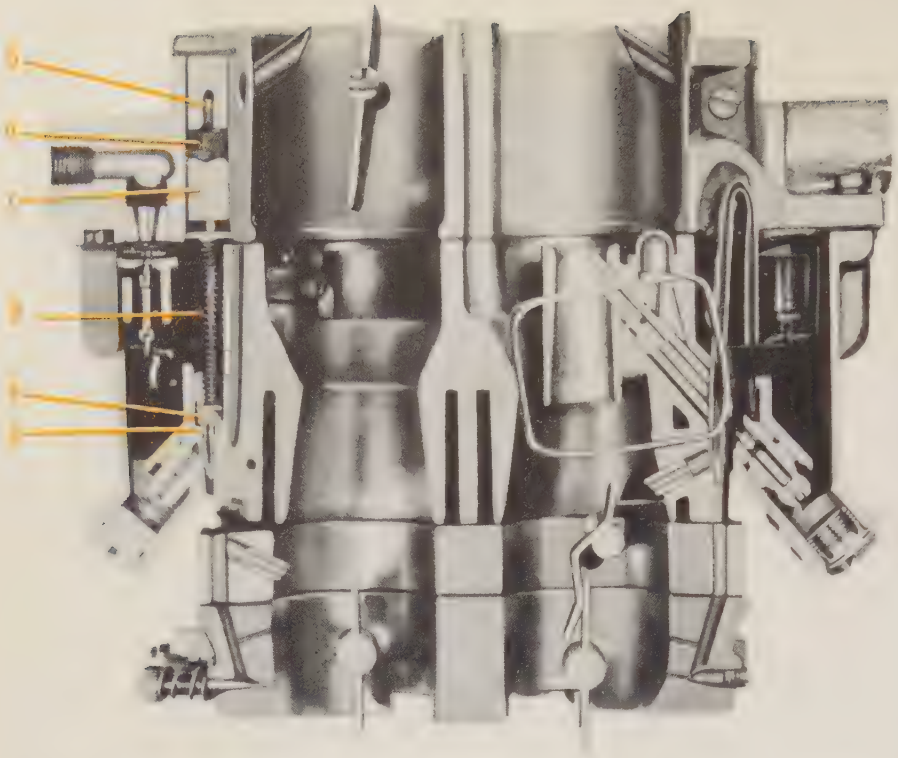


Fig. 5—Additional portion of primary carburetor is removed exposing section through power-enrichment device and right-hand main metering jet. *b* is a channel to intake manifold, *a* is the power-piston cylinder, *c* is the power piston, *d* is the piston spring, *e* is the power by-pass jet, *f* is a by-pass channel.

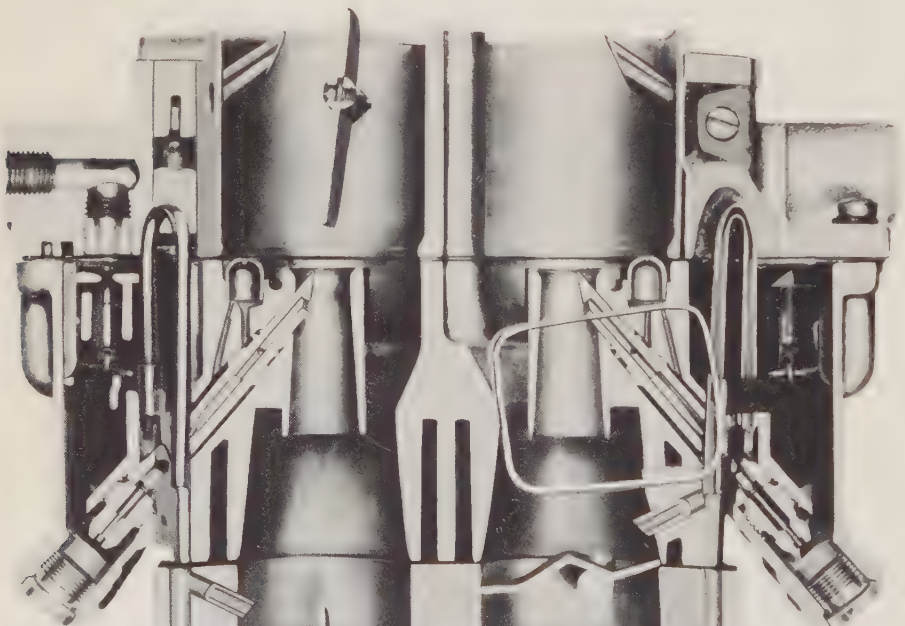


Fig. 6—Carburetor during full-throttle acceleration at very low speeds. The auxiliary throttle valve remains either completely or partially closed, depending on the engine rpm.

vapor bubbles are formed in the hot gasoline, the bubbles will follow the outside channel around the nozzle instead of passing through the nozzle tube. These vapor bubbles escape through the high-speed bleeder *Z* and thereby reduce percolating troubles.

Fig. 5 shows an additional portion of the primary carburetor removed exposing a section taken through the power-enrichment device and the right-hand main metering jet.

For maximum power or high-speed operation, a richer mixture is required in the primary carburetor than that necessary for normal throttle opening. The richer mixture is supplied through the main metering system of the primary unit by means of the power-enrichment device. In Fig. 5, power piston cylinder *a* is connected by a channel *b* to the intake manifold. At part-throttle position, shown by Fig. 4, the manifold vacuum is sufficient to hold the power piston *c* in its *up* position against the tension of the piston spring *d*. When the throttle valve is opened to a point where additional fuel is required for satisfactory operation, the manifold vacuum decreases sufficiently so that the piston spring moves the power piston down to open a metering hole in the power by-pass jet *e*. Opening of this metering by-pass jet allows additional fuel to enter the main discharge nozzle through a by-pass channel *f* without passing through the restricted main metering jet. Operation of the power-enrichment system just described is identical to that in the previous Buick dual carburetor.

In the secondary carburetor, the main metering system is identical to that of the primary unit except that the power-enrichment device is not present. The secondary carburetor functions only at high output and is therefore calibrated for the full, rich mixture corresponding to that supplied by the main carburetor with the enrichening device operating.

Throttle Valves

Idle Operation

Fig. 3 shows the carburetor during *idle operation*. Throttle valves *I* and *J* and auxiliary throttle valve *G* are closed. During part-throttle operation, the primary throttle valve *I* only is in operation.

Fig. 4 shows the carburetor functioning at the top of the *cruising speed* range. The primary throttle has opened sufficiently so that the loose lever and pick-up

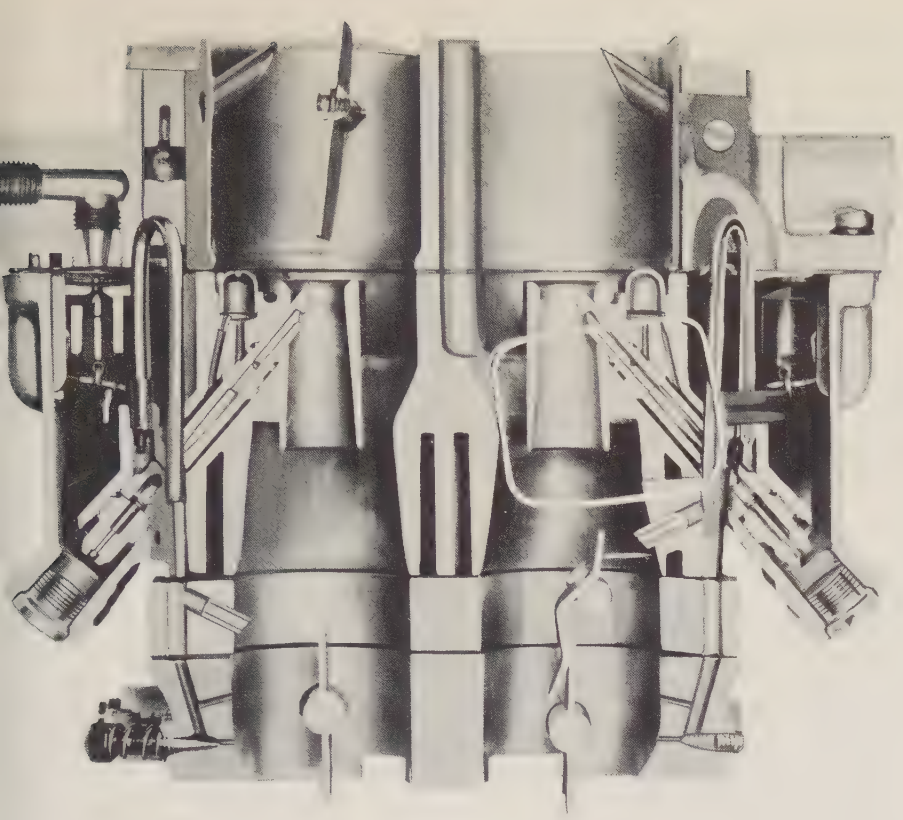


Fig. 7—Carburetor operating at wide-open throttle at high speeds.

linkage on the right-hand side of the unit is about to open the secondary throttle valve.

Full Throttle at Low Speeds

Fig. 6 shows the carburetor as it functions during *full-throttle acceleration* at very low speeds. Under these conditions, the auxiliary throttle valve remains either completely or partially closed, depending on engine rpm. Fuel metering during these periods is dependent for the greater part upon the main discharge system of the primary carburetor.

Full Throttle at High Speeds

Fig. 7 shows the carburetor operating at *wide-open throttle* above the cruising speed range. The main discharge systems of both carburetors function under this condition.

Summary

The Air Power Carburetor approaches another step closer to the ideal carburetor. It increases the horsepower output of an engine ten per cent over that obtained with a conventional dual carburetor. Economy is also improved from ten per cent at low and moderate speeds to five per cent at relatively high speeds. The unit is complete in one package, longer but no higher or wider than a standard dual carburetor. It requires no more attaching parts than a dual carburetor. The number and manner of adjustments are the same as a standard dual unit. Idling and performance are as smooth as any conventional dual carburetor.

Bibliography

Other related literature in this field includes the following:

MOSELEY, J. T. W., "Latest Ideas in Carburetion," *Journal of the S. A. E.*, Vol. 60, No. 6 (June 1952), p. 100.

SAVAGE, A. E., "More Miles Per Gallon . . . How to Save Gasoline," *Bus Transportation*, Vol. 30, No. 6 (June 1951), pp. 42-4.

FISHER, C. H., *Carburetion*, (London: Chapman and Hall, Ltd., 1952; Part II).

KUNS, R. F., *Automotive Essentials*, (Milwaukee: Bruce Publishing Company, 1951; 5th Edition), pp. 197-225.

A MESSAGE TO ENGINEERING EDUCATORS

about the

GENERAL MOTORS

Engineering JOURNAL

Your comments about the actual or potential teaching-aid value of specific manuscripts by our engineers and about the entire JOURNAL are always welcomed.

Working engineers, such as most of the JOURNAL's authors, seem singularly qualified to motivate students to study more thoroughly the fundamentals which you include in your courses. Our engineers, themselves having a firm grounding in basic engineering subject matter, seek mainly to demonstrate how the many areas of fundamental engineering knowledge diligently taught and studied in our colleges and universities are applied in industry.

Yet, without your comments it is difficult to know whether the JOURNAL is achieving its goal of contributing literature of value to engineering educators. Comments received from educators about the first three issues have been of great help—especially those comments which gave us a viewpoint on what type of information from industry is welcomed, used, and valued.

The JOURNAL is made available at no charge upon request by engineering faculty members and college professors of physics, chemistry, and mathematics. Extra copies will be supplied for classroom use on request.

Kenneth A. Meade

KENNETH A. MEADE,
Secretary, Advisory Board

Diesel Engine Improvements through Experimentation with Fuel Injection and Combustion Chamber Relationships

Considerable strides have been made in the development and application of Diesel engines in recent years. Much of this progress has been made possible by more efficient combustion of fuel. Exploratory study involves the determination of compatible injection and combustion-chamber combinations. An expedient method for such exploratory study carried out at Diesel Equipment Division shows how designs drawn from a knowledge of theory are advanced to a practical stage by experimental testing.

IN ENGINEERING a Diesel engine, it is important that the fuel-injection system and combustion-chamber developments be closely associated. This is required particularly in the two-stroke engine where scavenging of the cylinder also is critically related. *Scavenging* is the cyclic function of clearing the chamber of exhaust gases and replenishing it with air. Assuming efficient scavenging, the injection and combustion elements have a most important part in determining the essential features of engine performance, power output, and fuel economy.

Since the injection, combustion, and scavenging functions of the engine are so inter-related, one factor cannot be changed without the others being affected. There is adequate and excellent theoretical information on their inter-relationships, but experience has shown that behavior in a Diesel engine combustion chamber can be determined accurately only by the actual building and testing of experimental designs.

Conventional methods of fabricating experimental pistons and cylinder heads to study these three fields are both costly and time-consuming. One method of study which has proved successful at the Diesel Equipment Division makes use of interchangeable inserts made of common cold-rolled steel in both the cylinder heads and pistons. This method, explained below, has produced an accumulation of knowledge on a great number of inter-relationships. The only material requirements have been a variety of inserts and interchangeable injection systems of various types. Experimental cylinder heads and pistons normally require new castings for each change.

The study herein reported is intended as a case example of how an industrial laboratory obtained engineering information using a minimum of materials and manpower. It is important to understand the features of the basic engine chosen and the mechanisms which permitted it to serve as a basic engine.

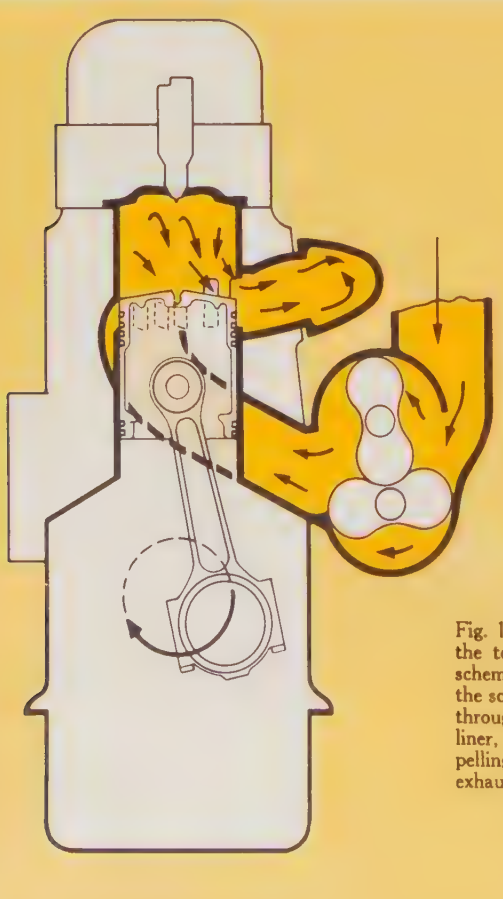


Fig. 1—The *loop-scavenged* system of the test engine is illustrated in this schematic diagram. Air supplied from the scavenging blower sweeps upward through intake ports in the cylinder liner, toward the cylinder head, expelling exhaust gases through radial exhaust ports also in the cylinder liner.

Engine and Mechanisms

Engine Features

The test engine was a conventional four-cylinder, two-stroke model, having no valves to obstruct changes in the cylinder head. It was of the so-called loop-scavenged type, having both inlet and exhaust ports in the cylinder. Burned gases were swept out by the incoming air which was supplied from a mechanically-driven blower which also charged the cylinder with fresh air for the next cycle (Fig. 1).

Details of Inserts

The inserts, mentioned above, made it possible to change with ease the shape of both the cylinder head and the pistons (Fig. 2). Inserts were made in a large variety of shapes to achieve almost any desired open-type chamber.

It might be of interest to describe the application of these inserts. The com-

By HERBERT H. BLACK

Diesel Equipment Division

Combustion factors can seldom be varied individually

ponents obviously required good structural character, capable of staying in place and yet readily removable. The inserts were threaded into a recess that was machined into the parent part and then tightened by a special spanner wrench. The piston inserts were sealed against pressure by a copper gasket while the cylinder-head inserts extended over the regular head gasket. A complete change of combustion chamber was accomplished by simply removing the cylinder head and changing these inserts. A direct-test comparison of identical combustion chambers with inserts against conventional parts indicated that performance was not abnormally affected.

From the foregoing observations, it is apparent that innumerable combinations of combustion chamber-injection factors are possible. While it is desirable to use the engineer's approach of changing one variable at a time, it is seldom possible on combustion tests. For example, a change of spray orifice simultaneously affects such conditions as injection pressure, rate of injection, atomization, and penetration. Furthermore, combinations found successful in one type of engine or with one design of combustion chamber are not necessarily applicable to others. However, the development of one type can lend impetus or raise the goal for another that may be more suitable from a structural, thermal, or performance standpoint. At any rate, it should be borne in mind that no generalities may be taken for granted. Suitable combinations of combustion-system factors are often peculiar to the individual type of engine. It may be noted that there are a great many different combinations in commercial usage.

Injection Systems

Provisions were available in the fuel-injection system to incorporate all manner of changes such as different types of nozzles, injection valves, timing adjustments, metering plunger sizes, and cam designs. Photographs of fuel sprays (in the atmosphere) produced by some of the different nozzles serve to illustrate their characteristics. First, consider the fixed-orifice type fuel injector which discharges the fuel at very high pressure through multiple orifices—in this case ten holes of 0.005 in. diameter (Fig. 3). Fig. 4 shows the spray from a *piston valve* nozzle in which larger orifices (0.007 in. diameter) are used. The amount that these holes are uncovered is controlled by a small piston whose travel is dictated by the internal pressure. The *variable orifice effect* of this type valve tends to assist atomization when smaller quantities of fuel are injected, as at part throttle. The others, such as pintle valves (Fig. 5) and poppet valves (Fig. 6) distribute the fuel in the form of a conical spray.

The Tests

A general combustion-chamber study was not involved in the tests to be described. The purpose, rather, was to obtain information on how some particular combustion-chamber characteristics are related to injection factors. For this reason, it was considered advantageous to adhere basically to one type of chamber (Fig. 7). Then, some of its details could be varied as needed to reveal compatability with features of the respective injection equipment.

In accordance with this plan, the combustion spacer was made to constitute a simple concentric cylindrical shape, with suitable radii, and having the injector nozzle centered in the top. This small cylindrical space could then be shifted to cover a wide range of experimentation from major volume in the cylinder head to major volume in the piston. The depth-diameter proportions could be varied, center displacers could be used, and some modification could be allowed in the general configuration.

It was found essential in all cases to minimize the clearance between the top surface of the piston and the cylinder head, thus moving the maximum available air into the combustion space. This was found particularly important when the combustion chamber was small and the piston rim was wide. It also served to squeeze, or *squish*, the air in at high velocity to create turbulence and induce intimate mixture with the fuel. The latter is advantageous in an engine where there is no other provision to create air movement. The maximum calculated air squish velocity is attained at about 8° before top center.

Fig. 2—A complete change of combustion chamber is provided by removal of the cylinder head and tightening of the inserts into place. The pistons do not need to be removed.

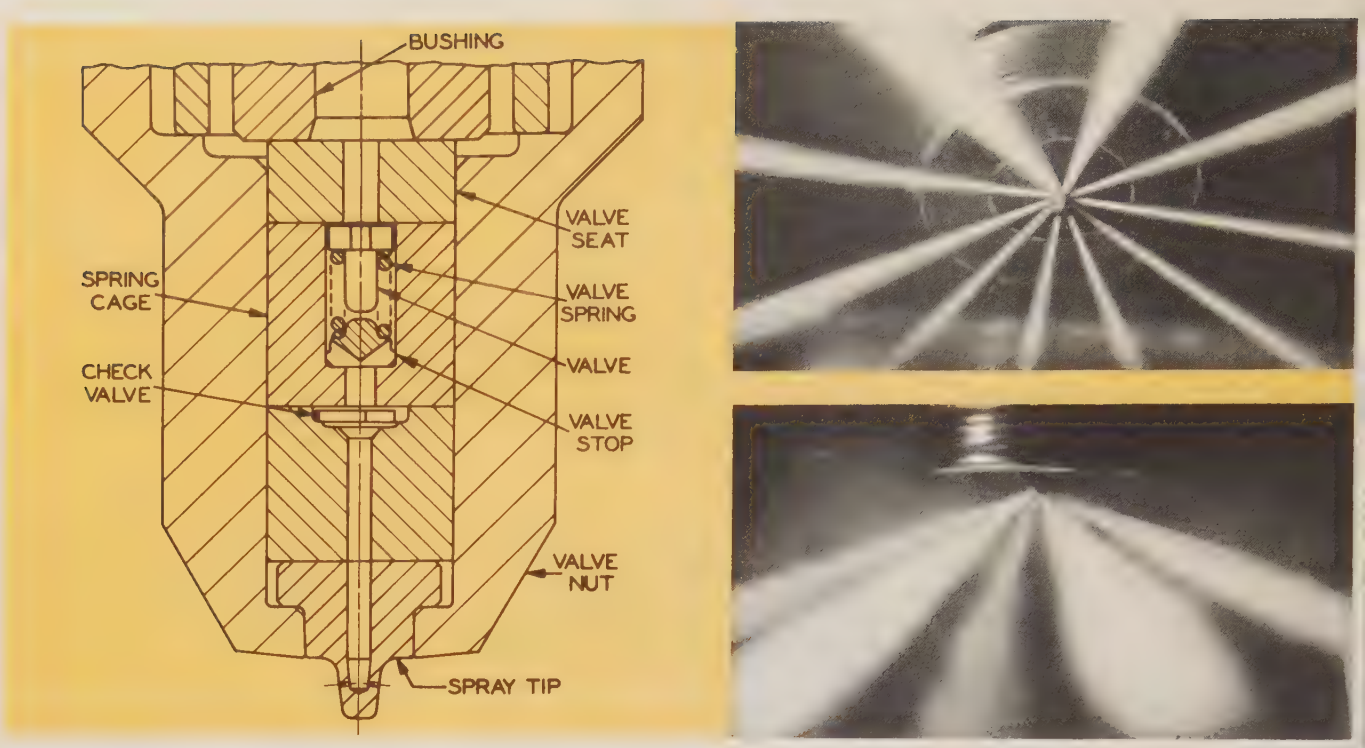


Fig. 3—Fixed multiple-orifice injection valve provides a uniform, spoke-type spray.

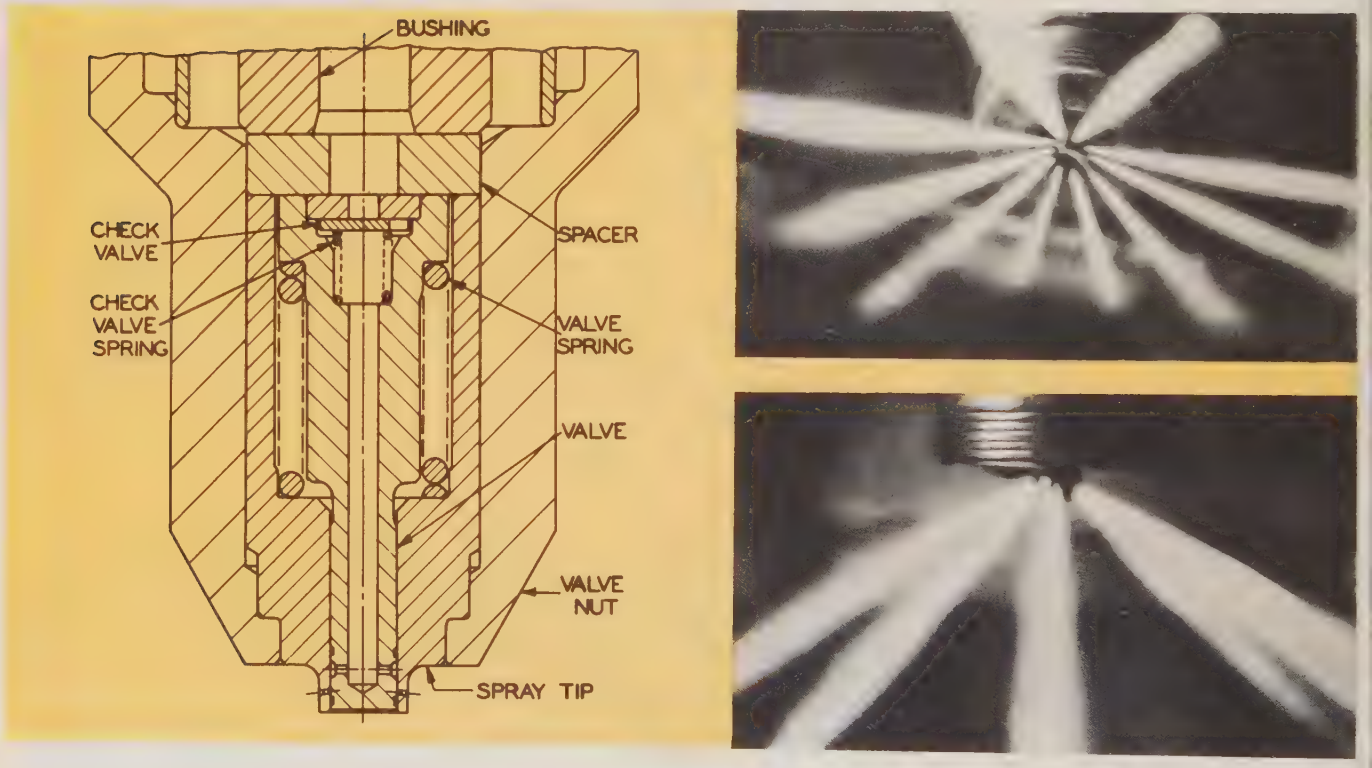


Fig. 4—Piston-valve nozzle and full-throttle (full-rack) spray. Good atomization of the spray is retained at part throttle.

In regard to compression ratio, 15.5:1 was found suitable for good performance, while 18:1 proved more satisfactory for starting advantages. These ratios were calculated on the basis of air volume in the cylinder at the time the top of the piston was even with the top of the exhaust ports.

In this series of tests, multiple, fixed-orifice injection nozzles, as illustrated in Fig. 3, gave good performance in the larger diameter combustion chambers, such as those shown in Figs. 7d and 8. In this assembly, a spring-loaded valve is used between the injection pumping

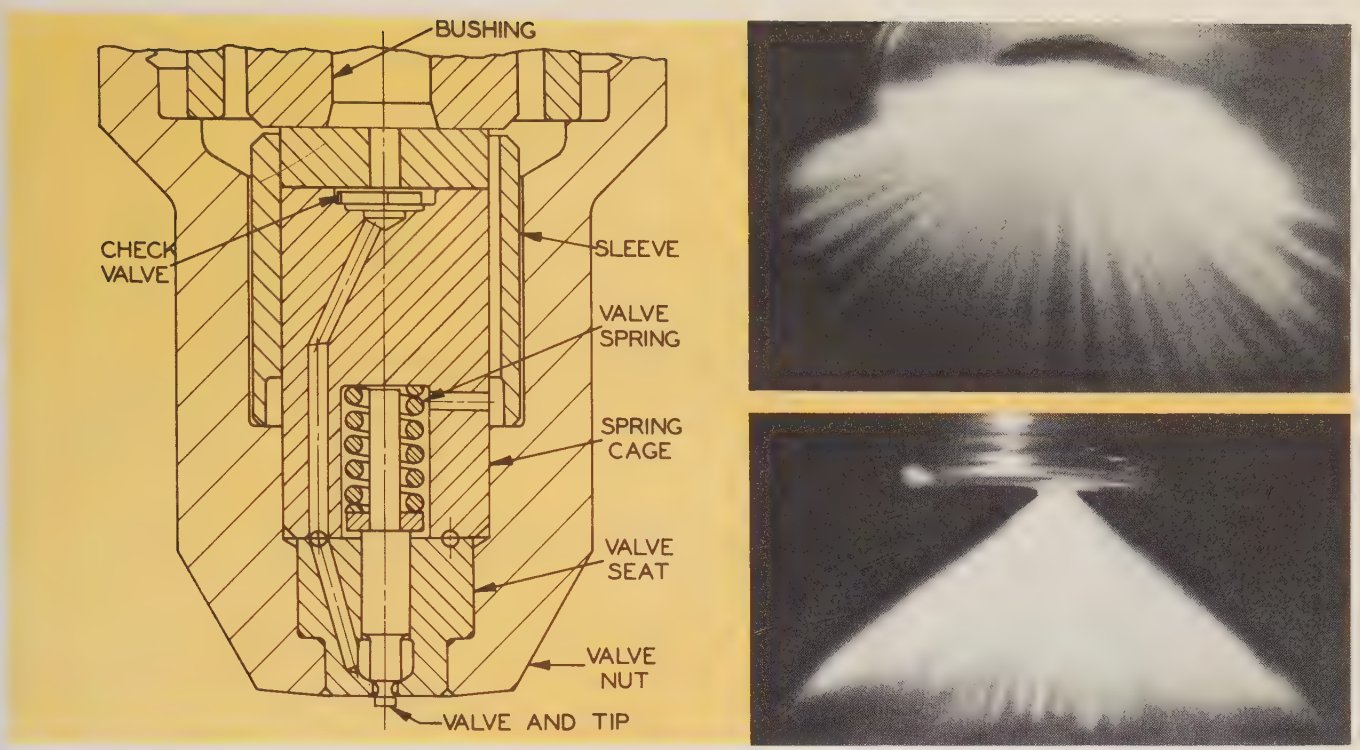


Fig. 5—Pintle-nozzle valve provides a continuous, conical spray. Included angle of cone is limited.

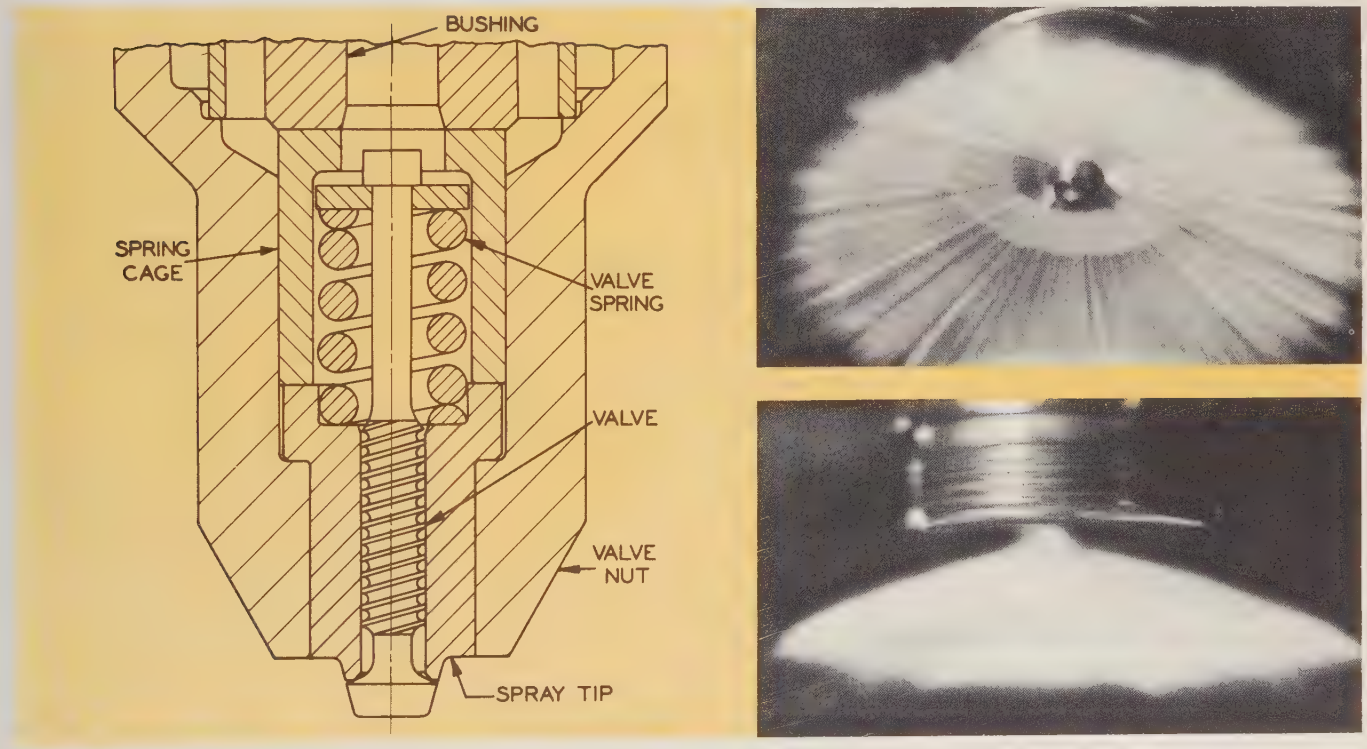


Fig. 6—Poppet valve provides a conical spray. Any desired angle of the cone can be provided.

plunger and the nozzle to retain the fuel and to provide positive control over the beginning and ending of fuel discharge. Near the extremity of the nozzle, the discharge holes are situated radially and at an angle dictated by the combustion chamber. Some compromise is made between the optimum orifice for low-speed performance and the avoidance of excessive restriction at high speeds. The average calculated fuel velocity at the tip was 1,500 ft per sec at an engine speed of 3,000 rpm.

The piston valve nozzle (Fig. 4) indicated advantages on part-load fuel econ-

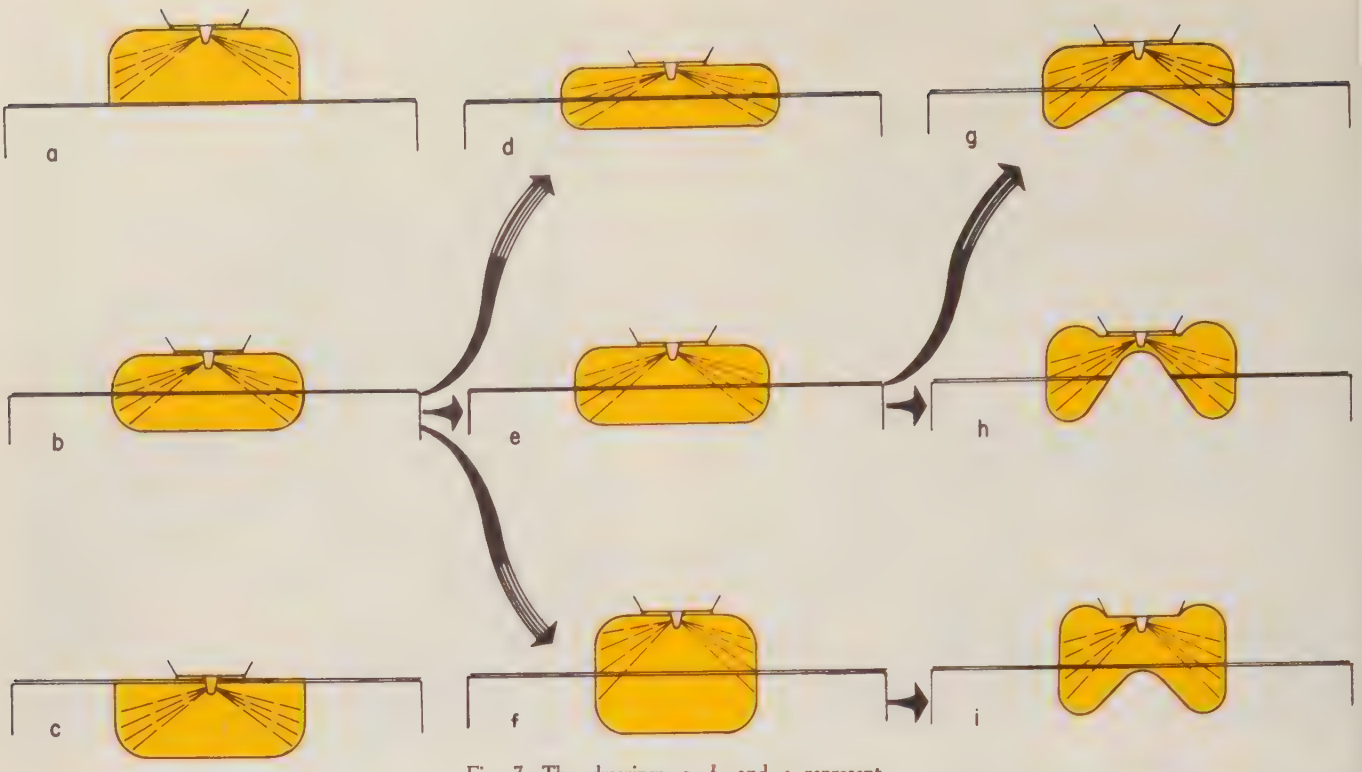


Fig. 7—The drawings *a*, *b*, and *c* represent extremes of combustion-chamber locations, while *d*, e, and *f* represent extremes of depth to diameter ratios. Drawings *g*, *h*, and *i* represent variations of shape and center cone.

omy. Using multiple orifices of a larger size, the nozzle was designed to throttle the orifices in relation to the quantity of fuel being injected. This valve gave its best performance when used in a combustion chamber smaller and deeper than the chamber required for the fixed-orifice nozzle.

Pintle and poppet nozzles (Figs. 5 and 6, respectively), having a peripheral opening and discharging an uninterrupted sheet of fuel, did not produce satisfactory power or fuel economy. It was considered likely that these types with their practically unrestricted opening and low-injection pressure would be more successful when mated with a relatively more compact combustion chamber. While this proved true to a certain extent, the engine performance, within the scope of this investigation, was unfavorable with these valves.

For use with the piston valve spray tip, tentative optimum proportions of the combustion chamber (Fig. 7g) placed 60 per cent of the volume in the cylinder head and 40 per cent in the piston. The overall depth of the combustion chamber was 0.38 of its diameter (0.38d) which was 0.46 of the cylinder diameter (0.46D). The injector nozzle was located so that the fuel spray was directed at the path of the inrushing air squeeze at the split line between the piston and head. A conical hump in the center of the piston was beneficial, its altitude being equal to the height of the piston rim.

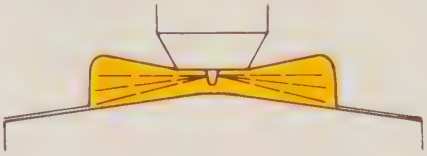


Fig. 8—Design falls into family of *Fig. 7a* with the chamber above the piston, and *Fig. 7d* with a relatively large diameter and a small depth. The maximum depth is *0.21d;* the diameter is *0.59D*.

A modification of the Fig. 7g design permitted the fuel spray to be elevated considerably above the split line. It may be assumed that the air motion followed a different path. Along with this change, it was found that other alterations of proportions contributed to a new favorable combination. In this design (Fig. 7i) the depth was 0.62d and the diameter was only 0.4D.

These three examples (Figs. 7g, 7i, and 8) proved to be favorable from the standpoint of fuel economy. It was also demonstrated that the more compact chambers, such as in Fig. 7g and 7i, were especially successful in conjunction with the piston-throttled nozzle shown in Fig. 4. This evidence, along with other results of similar nature, produced the conclusion that a reduction of injection pressure, and consequently less penetration, required a corresponding change in air distribution, i.e. volume distribution in the combustion chamber.

Summary

The results demonstrate that successful Diesel performance requires proper combinations of injection-system and combustion-chamber designs which may be attained through carefully coordinated experimental development. The work described herein continues with the goal of constantly adding to the present knowledge about the inter-relationships of injection-system and combustion-chamber designs. This method of study has the particular merit of enabling, with simple, inexpensive parts, great freedom of alteration of cylinder head and piston shapes. These shapes, combined with the use of interchangeable injection systems, offer wide areas of exploration for Diesel engine designers.

Acknowledgments

A large part of the experimental work described was conducted by Mr. Royce Engel, Jr., engineer on leave-of-absence to the United States Navy. The contributions of engineers of the Detroit Diesel Engine Division also are appreciatively acknowledged.

The Material-Utilization Activity in a Manufacturing Plant

By ROBERT F. SMITH
Delco Appliance Division

More and better products from less material

Two principal objectives—product improvement and cost reduction—are sought by every manufacturing plant in connection with the products it makes. Purchased materials are the most costly item used in the manufacture of many of today's products. Material-utilization programs have been established, therefore, to study every possible way to effect cost savings through the use of less material or different material—or both. Frequently, the result is that a single idea snowballs into a number of succeeding changes which an alert, well-coordinated materials group converts into startling savings as well as an improved product. A plant-wide organization, which need not be complicated, accomplishes these results most successfully.

ACTIVE material-utilization programs are making outstanding accomplishments by contributing to the reduction of material and manufacturing costs. Faced with rising wage and material costs, progressive manufacturing plants seek constantly to improve their products and yet maintain a competitive selling price.

Material utilization is the most economic use of both productive and non-productive materials involved in the processing and manufacture of all products. This may result in a new method involving a change in, or substitution of, materials—or a change in the usage of these materials. Material-utilization savings should include the labor and burden involved in making these changes. In a broad sense, effective material utilization offers a great opportunity for savings in the material used in the product itself as well as in the non-productive material used for the manufacture of the product.

The material-utilization program at the Delco Appliance Division is presented with the dual opportunity of making savings on extremely high-volume production and also on relatively low-volume production. Some of the items manufactured by this Division are end products while others—those representing the greatest volume—are used as components on other equipment. The principal products among the latter are small motors produced in a volume of nearly nine million a year. In the automotive field this includes motors for heater and defroster fans, electric window lifts, and seat and convertible-top actuators. In addition to the automotive applications, motors are produced for various home-laundry appliances, motion-picture projectors, calculating machines, and fans.

Others include home heating units and conversion burners, reciprocating and jet-type water pumps, automotive clocks, and synchro and servo motors for the defense program. Each of these products presents a different problem in manufacturing processes and techniques and, accordingly, the approach toward material utilization varies from product to product. On high-production items a small unit saving results in a large yearly saving, while on low-volume work a relatively large unit saving must be made in order to show an appreciable amount over a year's time.

Delco Appliance Division has no committee or commission set up to deal exclusively with the subject of material utilization per se. Instead, the *material-utilization plan* is integrated into a program established to cover the entire field of *product improvement*.

The problem is attacked in this manner primarily because it is felt that the various subjects covered are so closely allied that their fields frequently overlap. In order to eliminate the possibility of a duplication of effort and the time-consuming interchange of information between committees, a compact working group has been formed to cover all activities which lead toward a better product at a lower cost. Due to the number and diversity of the products manufactured, a single group to study all phases of every product tends to be large and cumbersome. For this reason, Delco Appliance Division's overall program is broken down into smaller groups, each of which directs its effort toward improving a particular type of product. One group studies heater motors, another, Delco-Heat products, a third, appliance motors, and so on. In this way, a complete coverage of all operations is established without placing an excessive burden on any one group of committee members, and the individual meetings do not become long and ineffective.

Fig. 1—An example of how material savings are made may be seen from the study of this field assembly of an automobile heater motor. Shown above is the assembly after adopting recommendations resulting from the material-utilization plan. Pressed into a stack of field laminations are two coils. Previously each one was insulated with a continuous length of cotton tape.

Each committee is composed of representatives from the Product Engineering Department, the Tool Engineering Department, the Industrial Engineering Department, the Process Engineering Department, the Plant Layout Department, the Inspection Department, and the Manufacturing Department concerned. Since virtually all of the Departments involved are represented on the committee, questions regarding the activities of these Departments are answered without delay and each Department has the opportunity to comment on any plan at its inception rather than being called in later. Complete cooperation between these Departments is required in order to insure the ultimate success of any plan; therefore, it is extremely advantageous to have all Departments correlate their activities from the outset. The close interdepartmental cooperation engendered by the product improvement committees contributes greatly to the success of the plan.

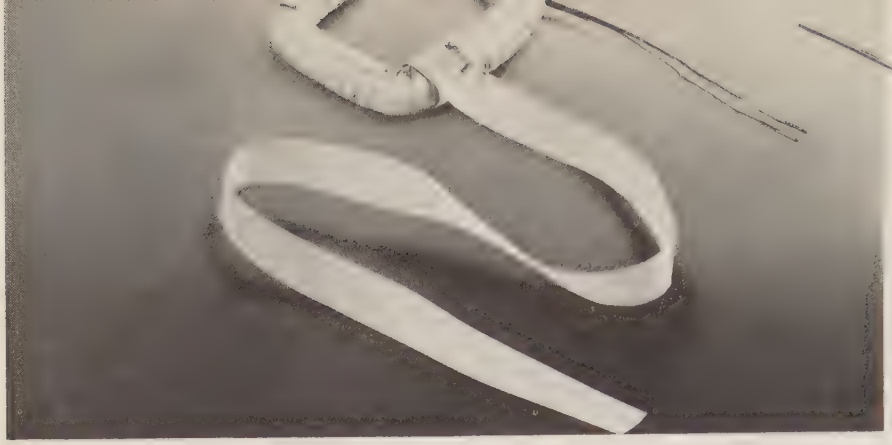


Fig. 2—Previous method of winding insulating material on field coils utilized a machine which wrapped each coil with a continuous length of ½-in. cotton tape approximately 5 ft long. The nature of the tape feed on the machine resulted in a short, wasted length of tape on every operation.

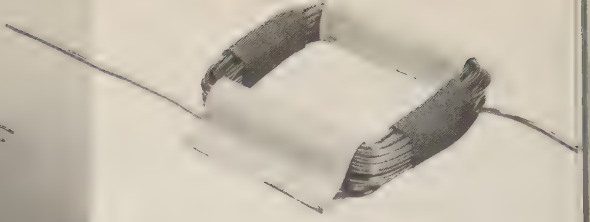


Fig. 3—A new method of insulating the coils using less expensive materials was found after an investigation by the Product Engineering Department and the Process Department. The coil shown above is insulated on two sides with one-in. wide, pressure-sensitive, cotton-backed tape. The other two sides are wrapped with 0.012-in. thick rag paper. The paper is specially treated so that after wrapping it can be sealed by the application of heat and pressure. Often, a single change in design and manufacture of a component makes possible several additional changes which result in a greater overall saving.

The committee is composed of the men who are the most familiar with the product under consideration as well as the methods and processes used to manufacture it. These are the men who actually work on the job; that is, they are on the operating rather than on the policy-making level.

A formalized program has many advantages, such as:

(a) New ideas are recorded
(b) Possibilities of application are increased by having all departments review the idea
(c) Suggestions are acted upon immediately
(d) Recognition by management improves employe relations.

The question most frequently asked about these product improvement meetings is: "What is your source of ideas?" or "How do you formulate the agenda for the meetings?". The improvements discussed and acted upon come from a variety of sources in the plant, from other General Motors Divisions, and from sources outside General Motors. A frequent source is the Division's employe suggestion system which results in the adoption of numerous worth-while ideas. The suggestions are screened before being brought up in the meeting so that only those with good possibilities are discussed. The supervision of the Manufacturing and Inspection Departments frequently bring up problems for discussion and, of course, wherever a problem exists there is always "room for improvement" which opens the door to new ideas.

Other sources are Product Engineering, Tool & Process Engineering, and the Plant Management groups. Many suggestions stem from visits to other General Motors Divisions and from General Motors committee meetings. It is not unusual to receive suggestions from customers, who are equally interested in product improvement. General Motors internal publications also contribute considerably toward the committee's efforts.

The most prolific source, however, is the nature of the work itself. That is, the agenda for these meetings is autogenous in nature and tends to be self-generating. One idea leads into another and that into a third and so on, until it has snowballed into something almost completely unrelated to the original idea. Very often, an improvement which has been developed and used in one place is applicable in another. It is advantageous, therefore, to keep the overall picture of the plant operations in mind while investigating improvements, since others will surely evolve from the work at hand. This Division is set up to take the maximum advantage from this situation, since it is built of men who specialize with regard to products rather than with regard to processes or parts. Therefore, each man, working on all phases of his Department's activities on a certain product, is able to follow through with any new development he encounters.

Considering all of these factors, it is easily understood that the problem is not to get enough material for discussion, but rather to keep the agenda small enough to be workable. Items on the agenda are not screened as to net value. The attitude that no item is too small to be considered must be preserved in order to get the maximum benefit from the program.

When a suggestion is brought before the committee, one or two of the members are appointed to study the problem. They obtain and present information at the meeting. The problem is then discussed in the light of the information reported, various possible solutions are considered, and the committee as a whole decides on the basic approach to be employed. A *target date* for completion is set and the men most intimately concerned are given the job of working out the details and following the project through. A brief progress report is made at each subsequent meeting and when the project has been finalized, a report of the improvements and the benefits derived from them is made and the results are entered in a permanent *product-improvement log*.

An understanding of the workings and scope of a product-improvement committee can be gained from a description of how improvements were made in the field assemblies of automotive heater motors. Completion of all aspects of this project took place over a period of several years. This example is typical of the type and range of the work covered by this committee and demonstrates how one idea leads logically to others, increasing the size and ultimate value of the project.

The field assembly of a heater motor is made up of two coils which are wound on arbors, insulated, and then pressed securely into a stack of field laminations (Fig. 1). Insulating the field coils was accomplished, before the start of this project, by wrapping the wire with a continuous length of ½-in. wide cotton tape approximately five ft long. This tape was applied by a machine which can be likened to a sewing machine in principle. An operator fed the coils through this machine by hand. Due to the nature of the *tape feed* of the machine there was a piece of tape slightly over one

ft long at the end of each coil which was not wrapped around the wire and was scrapped (Fig. 2).

The original project was solely an attempt to eliminate this waste tape. The task of studying the taping machine and deciding what revisions and alterations would be required to eliminate the unwrapped portion of tape was assigned to the Process Department. The study made by the Process Department proved to be completely abortive, and it was reported that no way could be found to eliminate the waste using the existing machine.

The Product Engineering Department and the Process Department were then assigned to work together toward finding a new method of insulating coils using less expensive materials. Investigations and experiments were conducted on many different possibilities until, at the end of a four or five month period, a method was found which satisfied all the requirements. Two sides of the coil were insulated with 1-in. wide pressure-sensitive, cotton-backed tape; the other sides were insulated with 0.012-in. thick rag paper. The rag paper was treated with a special material so that after the paper was wrapped around the wire it could be sealed by the application of heat and pressure (Fig. 3). This new method produced the desired result of saving material and cost.

It was then found, however, that a smaller winding arbor could be used with the new method of insulating and that, by substituting tools in places where hand operations had been in effect, the wire could be changed from two strands of light wire to one strand of heavy wire. The result was additional savings in the amount and the cost of the wire used.

In an attempt to further reduce the amount of wire used in the coils, the Engineering Department was assigned to investigate the possibility of reducing the height of the lamina stack which would permit still further reduction in the size of the coil-winding arbors. Although it was first believed that the size of the lamina stack could not be altered without affecting the performance of the motor, the resulting investigation proved that the width and length of the lamina could be reduced by 0.125 in. and the motor performance would be unaffected. Further study by the Tool Engineering Department indicated that, by improving the dies, a narrower strip stock could be used thereby reducing the offal from the blanking die by 0.078 in. on a side. The total of these changes resulted in a saving in lamination steel and a substantial cost saving based on a year's production.

Since the dies in use were obsoleted, the Tool Engineering Department made a study of new designs before building new dies. Experience at another General Motors Division had indicated good success with carbide dies. Based on the information supplied by that Division, the decision was made to use carbide dies for blanking the lamina. The increased life of the carbide dies means further savings in die costs as well as in decreased maintenance brought about by greater limit runs achieved with carbide dies.

The investigation of carbide dies prompted the same Division referred to above to suggest the use of hot-rolled steel to replace cold-rolled steel in motor laminations. Such a substitution had been successfully made by that Division and Delco Appliance, after its own further analysis, ultimately adopted this material for the manufacture of heater motors. While investigating the savings resulting from the use of carbide dies, another fact brought out was that over 40 per cent of the die maintenance was caused by breakage of the perforators for the rivet holes in the lamina. The Product Engineering Department and Process Engineering Department were assigned again to find a different method of securing the lamina together in order to eliminate the rivet holes. A system of arc welding the lamina stack in four places was the result of the investigation (Fig. 4). Thus, the savings were realized not only in die maintenance but also in material due to the substitution of welding for rivets. Furthermore, the removal of the rivet holes in the field lamina presents another opportunity to reduce the width of the lamina with resulting savings in material and motor cost.

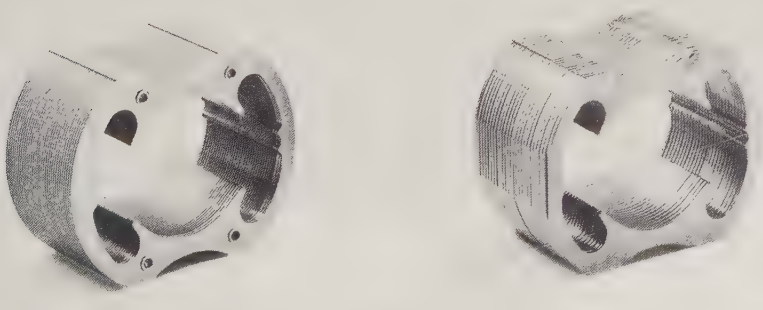


Fig. 4—The lamina stack formerly was joined together in a riveted construction (left). Using the new method, the stack is arc welded in four places eliminating material for rivets, eliminating rivet holes permitting a reduction in lamina width, and eliminating maintenance cost of the perforators for rivet holes.

Conclusion

This example shows that product improvement ideas do build up, one upon the other, like a snowball rolling downhill. A project which began as an investigation into a method for reducing the wasted amount of insulating tape resulted in the saving of the following additional materials:

- coil wire
- lamination steel strip stock
- rivets.

In addition, smaller arbors were used, carbide dies gave longer life with less maintenance, and hot-rolled steel replaced cold-rolled steel. Finally, the width of the lamina was reduced because of the elimination of rivet holes. By merely keeping alert for opportunities to save materials and by constantly watching for further possibilities for improvement, savings have been built up to a substantial amount on just one product. Each suggestion opens up new avenues for investigation to those who are enterprising enough to recognize them.

Experience at Delco Appliance Division indicates that the primary requisite for a successful material-utilization program is the development of an organization, properly integrated with the overall plant activities, which organization not only is "material-utilization conscious" but also constantly is alert for new possibilities and is aggressive enough to capitalize on its opportunities.

Notes About Inventions and Inventors

By CHARLES T. CROSS
Patent Section
Central Office Staff

Why was the pencil with an eraser added not patentable?

INVENTION is one of the most commonly used words in patent law, yet, in a patentable sense, one of the most difficult to define. While the statute says that a patent may be obtained for a "new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof," neither the statute nor the courts define what constitutes *invention* since, in the last analysis, the presence or absence of invention is generally determined subjectively in a particular case.

In the absence of a precise definition of invention, what should one look for to determine whether a new process or article is patentable? Clearly, the invention must be novel and useful to be patentable. Whether or not a particular proposal is novel is determined by the disclosure of prior patents and literature references, as well as prior actual operating devices and processes. However, in addition to being useful, the proposal must be more than merely novel in order to be patentable and any definition attempting to set forth what makes a novel proposal patentable is either misleading or too generalized to be of much practical value. In practice, a variety of factors must be considered in evaluating the patentability of a particular proposal. The standard of invention required by the U. S. Patent Office and the courts varies, not only with time, but with respect to different types of inventions.

There have developed through the years a number of so-called *negative rules* of invention which attempt to state what does not constitute invention. For example, it is said that combining into one structure two or more features which do not cooperate to produce the desired result is merely aggregative and does not constitute invention. One case often cited in support of this contention deals with a lead pencil carrying an eraser at one end. In this case the U. S. Supreme Court held that no invention was involved inasmuch as the pencil and the eraser did not cooperate to produce the desired result—the pencil and eraser each being used independently of each other. However, to this and the other so-called general rules there are numerous exceptions which vary from time to time depending upon the particular facts and which often render any general rules misleading.

Accordingly, whenever a new proposal or device, or some improvement in a prior article, machine, or process comes to mind which has important advantages or offers substantial savings, the best procedure is to submit the proposal to a patent attorney. The patent attorney, being familiar with the current court decisions and U. S. Patent Office practice with respect to the particular art, is in the best position to evaluate the possibility of obtaining a patent.

In General Motors, all new proposals are submitted for evaluation by patent attorneys who, in most instances, are also engineers. A valid United States patent cannot be obtained if the proposal has, for more than one year prior to the filing date of the patent application, been in public use or on sale in the United States, or described in a printed publication anywhere. If the proposal is sufficiently useful and the patent attorney and inventor are not aware of such a statutory bar, or that the invention has been known or used by others in this country, or patented or described in a printed publication in this or a foreign country before the present invention, a patent application is prepared.

A problem, at times equally as perplexing as the question of what constitutes invention, is the problem of determining who is an inventor or inventors in a patent application. Especially is this true where an apparently patentable idea originates in a group conference or through the work of a research team or group of engineers working on a particular problem. In the United States, a patent application must be filed in the name of only the person or persons who are actually inventors. In interference proceedings in the U. S. Patent Office to establish priority of invention, as well as in possible later court proceedings, the details of how and when the invention was made may have to be proved.

The person who conceives the novel idea and reduces it to practice clearly is an inventor. However, in many instances, another person contributes something which completes the invention and makes it workable. In such a case, if the second person's contribution is real and substantial, involving more than routine skill or knowledge, the invention is a joint invention and any patent application is filed in the names of both persons. On the other hand, since an idea itself is not patentable, if one person has an idea without any explanation as to how it is to be put in practice and if a second person alone devises means to make the idea work—then the second person is the sole inventor.

On this and the following pages are listed some of the patents granted during the period from September 1 to October 15. The brief patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each patent.

• **Josue R. Picon,** *Patent Section, Central Office, Detroit, Michigan, for a Windshield Wiper, No. 2,651,800, issued September 15.* This invention is drawn to a windshield wiper blade for curved windshields, the blade employing a flexible backing strip having a plurality of short tapered wiper blade sections mounted thereon, each of the wiper blade sections having a metal strip passing through a bore in the head portion which is clamped against the backing strip.

Mr. Picon is chief draftsman in the Patent Section. Mr. Picon is a graduate of the School of Arts, Lima, Peru, and he also attended University of Michigan. This is the second patent granted as a result of his work.

• **Henry H. Harada,** *AC Spark Plug Division, Flint, Michigan, for a Remote Electrical Drive Unit, No. 2,652,471, issued September 15.* This patent relates to an electric drive unit for electric speedometers or other instruments and utilizes a contactor operable through the speedometer cover cooperating with a spring-biased rotor contactor to permit operating a remote instrument from a local rotating mechanism.

Mr. Harada is a senior designer in the Engineering Department at AC Spark Plug. Originally employed in July 1926 by the Division as a draftsman, he was promoted to designer in 1933 and to senior designer in 1946. At present, Mr. Harada is doing developmental work on speedometers. His past work on odometers, remote electrical-drive units, direction signals, and gearless-type pressure gauges has resulted in seven patents.

• **Thomas C. Van Degrift, Charles W. Gadd, and Ralph S. Matsen,** *Research Laboratories Division, Detroit, Michigan, for a Combustion Chamber Pressure Indicator, No. 2,652,517, issued September 15.* This patent is drawn to a modified spark plug having a flexible wall on which strain gage wire is mounted to permit both igniting a fuel mixture and measuring the resultant pressure in a combustion chamber.

Mr. Van Degrift's biography is published in the Contributors' Section of this issue of the JOURNAL.

Mr. Gadd is supervisor of vibration and stress analysis in the Special Problems Department of the Research Laboratories. After receiving the B.S.M.E. degree from Massachusetts Institute of Technology in 1937, he joined the Research Laboratories as a junior engineer. He was promoted to research engineer in 1941, to senior engineer in 1947, and to his present position in 1953. Mr. Gadd supervises a section that handles the projects being carried out in vibration and stress studies. His work has resulted in three patents granted and several published papers on the strength of metals. Mr. Gadd is a member of the American Society of Mechanical Engineers and is chairman of the Papers Committee of the Society for Experimental Stress Analysis.

Mr. Matsen is a junior engineer in the Special Problems Department of Research Laboratories. Originally employed in 1949 in the college-graduate-in-training program, Mr. Matsen was assigned to the Special Problems Department. He earned the B.S.M.E. degree from University of Colorado in 1949 where he became a member of Pi Tau Sigma, Sigma Tau, and Tau Beta Pi. Mr. Matsen served as a pilot in the Army Air Corps from 1943 to 1945 attaining the rank of second lieutenant. At present, Mr. Matsen is on military leave serving in the Air Corps.

• **Walter B. Herndon, Ralph F. Beck, and William L. Tuschak,** *Detroit Transmission Division, Ypsilanti, Michigan, for a Fluid Flywheel Construction, No. 2,652,782, issued September 22.* The invention is directed to a fluid flywheel construction having slots provided in the outer and inner torus members as well as in the individual blades to facilitate assembly and to provide a strong structure when assembled.

Mr. Herndon is works manager at Detroit Transmission. He was initially employed by GM in 1928 as a tool designer at Cadillac Motor Car Division. He transferred to Detroit Transmission Division in 1939 as assistant general manager. He subsequently became assistant chief engineer, chief engineer, and director of engineering sales before appointment to his present position in July 1953. Mr. Herndon was engaged in the early design of the Hydra-Matic transmission and his work has resulted in five patents in this field. He received the B.S.E. degree from the State College of Washington in 1924, and the M.S.E. degree from the University of Michigan in 1930. He is a member of the Engineering Society of Detroit and the S.A.E.

Mr. Beck is a staff engineer in the Engineering Department at Detroit Transmission. His initial employment with General Motors was at Cadillac Motor Car Division in 1925 as a chassis layout man. He transferred to Detroit Transmission Division in 1939 as project engineer, was promoted to senior project engineer in 1942, to production engineer in 1948, and to chief draftsman in 1950. He was promoted to his present position, staff engineer, in 1951, in which capacity he is responsible for converter development. Mr. Beck is a member of various technical committees: the S.A.E. Technical Committee on Synthetic Rubber, the Drafting Standards Committee of the A.S.M.E., and the GM Drafting Standards Committee.

Mr. Tuschak is supervisor of engineering drafting in the Engineering Department at Detroit Transmission. His General Motors employment began in 1942 when he started as a junior detailer at this Division. He was promoted to detailer in 1943, to senior detailer in 1944, and to layout man in 1948. In 1952 he was appointed to his present position. This is the first patent granted as a result of Mr. Tuschak's work in transmission design.

• **Leo B. Nemmer and Charles J. O'Brien,** *Harrison Radiator Division, Lockport, New York, for a Valve for Lubricant Temperature Regulating System, No. 2,650,767, issued September 1.* This invention is an oil cooler for aircraft and other engines in which a thermostatically-operated valve is provided for by-passing the cooler when the oil is cold.

Mr. Nemmer is no longer with the Division.

Mr. O'Brien serves as senior engineer—research and experimental in the Engineering Department of Harrison Radiator. Immediately after receiving the B.S.M.E. degree from Clarkson College of Technology in 1927, Mr. O'Brien was employed by Harrison Radiator as an engineer. His major promotions since then include: technical data supervisor in 1930, junior engineer in 1934, development engineer in 1936, research engineer in 1940, assistant section engineer in 1942, and his present position in October 1948. Mr. O'Brien has done previous developmental work on heat exchangers, aviation oil cooler valves, locomotive oil coolers, and aluminum radiators—in addition to his present work on thermostats.

• **Louis Muchy,** *Fisher Body Division, Detroit, Michigan, for a Method of and Apparatus for Attaching Clinch Nuts to Sheet Metal Members, No. 2,652,942, issued September 22.* This patent relates to a method and apparatus for attaching clinch nuts to sheet metal. A clinch nut held on a punch is driven through a metal sheet supported by a die which is then successively retracted, rotated, and moved into engagement with the nut to stake it to the sheet.

Mr. Muchy is assistant plant manager of Fisher Body's Process Development Plant. He was originally employed by General Motors in 1924 as a machinist at one of Fisher Body Division's Detroit plants and was promoted to foreman in

1927. In 1937 he became foreman at the Die and Machine Plant of Fisher Body. He was promoted in 1940 to general superintendent of the Division's Central Development and Experimental Unit which later became known as the Process Development Plant. He was promoted to his present position in 1945. This is the first patent granted as a result of Mr. Muchy's work in developing and perfecting new manufacturing processes. He is a member of the S. A. E.

• **Nelson Walker,** *AC Spark Plug Division, Flint, Michigan, for a Tank Closure, No. 2,652,945, issued September 22.* This invention is a filler cap for gas tanks in which a novel valve is employed to vent the tank but to prevent the escape of liquid therefrom.

Mr. Walker is project engineer in the Engineering Department of AC Spark Plug. He has been with General Motors since 1923 when he started at the Chevrolet Motor Division in Flint, Michigan, as a tool and gauge maker. Shortly afterward, he transferred to the Buick Motor Division in a similar capacity and in 1926 he transferred to AC Spark Plug. In the Engineering Department at AC, he held the position of draftsman and was advanced to designer in 1940. He was appointed to his present position in 1951. Included in his work have been designs for pressure caps and overflow valves for radiators, several of which resulted in patents.

• **William J. Purchas, Jr. and Edward Orent,** *Diesel Equipment Division, Grand Rapids, Michigan, for a Duplex Nozzle, No. 2,653,054, issued September 22.* This invention is in fuel spray nozzles of large capacity for gas turbine engines. The nozzles are of the swirl type having a novel valve which cuts off the flow to one set of swirl ports when the rate of flow is small.

Mr. Purchas is chief engineer in the Engineering Department of Diesel Equipment. He received the B.S.M.E. degree from Detroit Institute of Technology in 1933. Mr. Purchas began his career with General Motors in January 1936 as a dynamometer operator with the Research Laboratories Division. In late 1936 he was promoted to the Drafting Department engaged in injection design. In 1938 he transferred to the Detroit Diesel Engine Division as project engineer on fuel injection. In 1945 he became a senior engineer at Diesel Equipment Division and in 1949 he was promoted to chief engineer, his present position. This is the third patent granted as a result of Mr. Purchas' work with fuel injectors and jet nozzles. He is a member of the S.A.E. and the Engineering Society of Detroit.

Mr. Orent is superintendent of Aeroproducts activities in the Production Department at Diesel Equipment. He was originally employed by Detroit Transmission Division in 1944 as design layout engineer in the Engineering Department. In 1945 he transferred to the Diesel Equipment Division as a design checker. He was promoted to project engineer in 1946, to senior project engineer in 1950, and to superintendent of Aeroproducts activities in 1953. Mr. Orent received the B.S.M.E. degree from University of Michigan in 1944. He is a member of the Society of Automotive Engineers, Phi Kappa Phi, and Tau Beta Pi.

• **Henry S. Kawecki and Chester J. Glowzinski,** *Cadillac Motor Car Division, Detroit, Michigan, for a Parking Brake Indicator Light, No. 2,653,197, issued September 22.* This patent is directed to a hand-brake warning signal switch actuating mechanism operated by the emergency brake lever, a warning light being actuated when the circuit is closed while the brake is not in the released position.

Mr. Kawecki is assistant staff engineer in the Body Department at Cadillac Motor Car. He joined the Division in 1927 as a draftsman. Since that time, he has advanced through several positions on Cadillac's engineering staff including chief checker and project engineer in the Body Department. He was promoted to his present position in 1940. During World War II, Mr. Kawecki served as an engineer on the Cadillac Tank Program. He is a member of the Engineering Society of Detroit and serves on the Educational Committee and the Standards Committee of the American Society of Body Engineers.

Mr. Glowzinski is senior project engineer in the Electrical Department of the Cadillac Motor Car engineering staff. He has been with the Division since 1927 when he was employed as a blueprint trimmer. Mr. Glowzinski has been promoted through the positions of senior layout and designer to his present position, which he has held since 1950. This is the first patent granted as a result of his work with indicator lights. He is a member of the American Society of Body Engineers.

• **Robert W. Guernsey and Ray C. Ulrey,** *Detroit Diesel Engine Division, Wayne, Michigan, and Detroit, Michigan, respectively, for a Flexible Link Drive for Isolating Torsional Vibration, No. 2,653,457, issued September 29.* This invention relates to torsional vibration absorbing couplings adapted to exert a vibration dampening torque that is a function of their phase displacement and the angular velocity of the rotating member.

Mr. Guernsey is senior engineer in the Engineering Department of the Wayne, Michigan, plant of Detroit Diesel Engine Division, a position which he has held since 1950. He has been with this Division since 1940 and much of his work has been devoted to the technical problems of design and development of Diesel engines. Prior to 1940, he was associated with the Chevrolet Engineering Laboratory for seven years as a test assistant. He holds the B.A., B.S. in Engineering, and the M.E. degrees from Columbia University. Two patents have resulted from his work on torsional vibration and power transmission. He participates in two S.A.E. committee activities and has contributed to the *Transactions* of S.A.E.

Mr. Ulrey serves as a senior designer in the Engineering Department at Detroit Diesel. He began employment with the Division in 1946 in this capacity. Mr. Ulrey earned the B.S.M.E. degree in 1936 from Purdue University. Previous to employment with General Motors, he served as a design engineer with the Ingersoll-Rand Company. This is the first patent resulting from Mr. Ulrey's work with Diesel engines. Mr. Ulrey served in the U. S. Air Force from 1942 to 1946, separating with the rank of major.

• **Carlton A. Rasmussen and Robert T. Doughty,** *Cadillac Motor Car Division, Detroit, Michigan, for a Valve Spring Surge Damping and Valve Rotating Device, No. 2,653,587, issued September 29.* This patent covers various arrangements of Belleville spring type washers inserted under the return spring of an engine poppet valve, together with different prong formations integral with either the Belleville or the valve return spring to reduce surging while achieving a progressive valve rotation.

Mr. Rasmussen is special assignment engineer at Cadillac Motor Car. After

receiving the B.S.M.E. degree from Purdue University in 1940, he joined Cadillac Motor Car Division as a laboratory technician in the Engineering Laboratory. One of Mr. Rasmussen's previous major assignments was the planning and construction of the Engineering Laboratory at Cadillac Motor Car. This is the first patent granted as a result of his work with engines. His committee memberships include the S.A.E. Passenger Car Activity Committee and the Ordnance Technical Center Planning Sub-committee of the Automobile Manufacturers Association.

Mr. Doughty is senior project engineer at Cadillac Motor Car. He was first employed by the Division as a laboratory technician in 1943 after receiving the B.S. degree from Tri-State College. In 1947 he was promoted to project engineer and in 1950 he became senior project engineer—all positions being on Cadillac's engineering staff. Mr. Doughty's current projects are related to motor mounts and exhaust systems. His work in engine design, which has included cooling systems and crankcase ventilation, has led to four patents. He is a member of the S.A.E. and the Engineering Society of Detroit.

• **Edward W. Lape, Oren F. Flaugh, and Richard E. Moore,** *Aeroproducts Operations of Allison Division, Dayton, Ohio, for an Accumulator Feathering System for Variable Pitch Propeller Control, No. 2,653,669, issued September 29.* The patent relates to a variable pitch propeller having fluid motors for adjusting the pitch position of the propeller blades. The actuating system for the fluid motor includes propeller-driven pumps which are operable to charge an accumulator, and an accumulator control valve.

Mr. Lape is senior checker at Aeroproducts Operations of Allison. He originally was employed by Aeroproducts as a senior detailer in March 1942. He was promoted in August 1942 to checker and in January 1953 to senior checker. Mr. Lape earned the Bachelor of Science degree from Bethany College in 1916. Presently, he is connected with work on the hub section of a supersonic propeller. In the past, he worked on the hub section of both production and experimental propellers.

Mr. Flaugh is a designer at Aeroproducts Operations of Allison. He initially was employed by the Division in December 1942 as a senior detailer. He was promoted to his present position in March 1945. Mr. Flaugh earned the B.S. degree in mechanical engineering from Tri-State College in 1931. This is the first United States patent granted as a result of Mr. Flaugh's work with airplane propellers and actuators.

Mr. Moore is no longer with the Division.

• **William H. Manning and Kenneth L. Hulsing,** *Central Office, Detroit, Michigan, and Detroit Diesel Engine Division, Detroit, Michigan, respectively, for a Drive Seal Retainer, No. 2,653,728, issued September 29.* This covers a sheet metal plug in the form of a disk having a central threaded button secured thereto which facilitates deforming the disk to a dished shape to permit its installation and removal from the opening to be closed.

At the time of his death in August 1951, **Mr. Manning** had served for five years as technical assistant to R. K. Evans, General Motors vice president. Mr. Manning joined the GM Research Laboratories in Dayton, Ohio, in 1924. In 1926, while on assignment with Buick Motor Division, he developed Buick's first counterweighted and balanced crankshaft. Later, he worked with Pontiac Motor Division on a special engine-design program.

Mr. Hulsing is chief application engineer at Detroit Diesel Engine. He began employment at this Division in 1942 as an analyst in the Engineering Department. He was promoted to assistant director of the Engineering Laboratory in 1952 and to his present position in 1953, in which capacity he is concerned with Diesel engine applications. In the past he has worked on loop-scavenged 2-cycle Diesel engines, automatic injectors, and air-cooled Diesel engines. Mr. Hulsing earned the B.S.Ch.E. degree from University of Michigan in 1936. Five patents and two published papers have resulted from his work in Diesel engines. He is a member of the Society for Experimental Stress Analysis and the American Society for Metals.

• **James L. Arthur,** *Allison Division, Indianapolis, Indiana, for a Connector Assembly, No. 2,654,078, issued September 29.* This patent pertains to a self-locking screw and terminal assembly comprising an internally-threaded stud having a tapered end and longitudinally-slotted walls, a connective member having an unthreaded sleeve portion, and a screw which passes through the sleeve portion and is threaded in the stud.

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.

Mr. Arthur is general supervisor of the Electronics and Parts Test Laboratory at Allison. In 1916 Mr. Arthur joined the Remy Electric Company, which later became Delco-Remy Division, as a laboratory engineer. In 1942 he transferred to Allison Division as an ignition electrical engineer. His previous work at Delco-Remy was on the design of ignition distributors, vacuum advance distributors, and associated automobile equipment. This is the second patent resulting from Mr. Arthur's work with aircraft components. He is a member of the Society of Automotive Engineers.

• **George R. Squibb and Donald A. Urquhart,** *Process Development Section, Detroit, Michigan, for a Process and Apparatus for Grinding, No. 2,654,977, issued October 13.* This patent is drawn to a process of making piston rings by continuously moving the rings in one direction across the surface of a grinding wheel. The rings are contracted and expanded as they pass the wheel and are frictionally rotated with the grinding wheel by positive driving means.

Mr. Squibb is chief project engineer in the Process Development Section. Originally employed by the Section in 1949 as a senior project engineer, he was promoted to chief project engineer in November 1950. In 1933 Mr. Squibb received the B.S.M.E. and B.S.A.E. degrees from University of Michigan where he was elected to Tau Beta Pi. Prior to joining General Motors, most of his experience was with Cincinnati Milling Machine Company. His work on broaching machines and broaching tools have resulted in two patents and numerous talks and published papers. Mr. Squibb is a registered professional engineer in Michigan and Ohio. He is a past chairman of the Cincinnati Section of the American Society of Tool Engineers and is a member of the Engineering Society of Detroit.

Mr. Urquhart is no longer with the Section.

• **Frederick W. Chapman,** *Research Laboratories Division, Detroit, Michigan, for a Frequency Modulated Torsional Vibration Analyzer, No. 2,655,036, issued October 13.* This patent relates to an electronic measuring apparatus that operates on the frequency modulation principle and is automatically adjusted to follow the speed variations of a shaft, the torsional oscillations of which are to be measured.

Mr. Chapman is a senior engineer in the Physics and Instrumentation Department at the Research Laboratories. Starting as a junior engineer with the Division in 1939, he was promoted to research engineer in 1943 and to senior engineer in 1952. Mr. Chapman received the B.S.E.E. degree from University of Michigan in 1938. Previous to his current work on the development of electronic contour-following devices, he developed electronic equipment for various types of instrumentation. Mr. Chapman has authored papers on a method for measuring the oxygen saturation of the blood and an improved indicator for measuring static and dynamic pressures. He is the present chairman of the Detroit Section of the Institute of Radio Engineers and is a member of the Engineering Society of Detroit.

• **Herbert A. Krause,** *Electro-Motive Division, LaGrange, Illinois, for a Brush Spring Retractor, No. 2,655,061, issued October 13.* This invention relates to a tool for retracting spring fingers of pre-loaded coil springs and comprises a pivotable L-headed structure having finger engaging means on the leg portions.

Mr. Krause is a project engineer in the Electrical Control Laboratory at Electro-Motive. He originally was employed by the Division in 1943 as a test mechanic in the Electrical Test Department. In 1944 he was made electrical tester and in 1946 he was promoted to experimental test mechanic. He became a project engineer in 1951. Mr. Krause received a diploma in electrical engineering in 1950 from International School of Correspondence. This is the second patent resulting from his work in motor and generator maintenance tool development.

• **Carl A. Bierlein,** *Cleveland Diesel Engine Division, Cleveland, Ohio, for Pump Priming, No. 2,655,139, issued October 13.* This patent is directed to an arrangement of fresh water and sea water pumps used for cooling a marine engine whereby the sea water pump is at all times primed by means of an evacuator operating in response to water flow through a by-pass line.

Mr. Bierlein is director of the Inspection and Test Department at Cleveland Diesel Engine. His GM career began in 1929 when he was employed by Buick Motor Division as a General Motors Institute cooperative student. He holds the B.S.M.E. degree from G. M. I. He transferred to Cleveland Diesel Engine Division in 1933 where he has held various positions relating to manufacturing work including foreman of the Injector Department, superintendent of experimental test, and senior experimental engineer.

• **Mearick Funkhouser,** *Delco Products Division, Dayton, Ohio, for a Shock Absorber, No. 2,655,233, issued October 13.* This invention relates to fluid flow control of a shock absorber wherein disk-type valves are provided to control the flow of fluid between opposite sides of the shock absorber piston, each disk valve having an orifice to provide restrictive flow under certain conditions, and a control valve to regulate closing the orifice.

Mr. Funkhouser is chief engineer in the Engineering Department at Delco Products. In 1933, Mr. Funkhouser started at this Division as an inspector. He was promoted through the positions of laboratory engineer in the Shock Absorber Laboratory in 1933, senior design engineer in 1942, section engineer in 1944, assistant chief engineer in 1945, and chief engineer, his present position, in 1951. Mr. Funkhouser earned the mechanical engineering degree in 1932 from Cornell University. He is a member of the Society of Automotive Engineers.

• **Theodore J. Soroka,** *Chevrolet Motor Division, Detroit, Michigan, for a Fender Shield, No. 2,655,389, issued October 13.* This invention is a fender shield pivotable at its bottom edge on trunnions engaging supports at opposite ends of the fender opening. The top of the shield is movable outwardly within the fender opening by a rotatable latch which causes the shield flange to tightly engage the fender flange against a gasket therebetween.

Mr. Soroka is body-design engineer in the Engineering Department of Chevrolet's Central Office. Mr. Soroka has been with this Division during his entire General Motors career which started in 1930 when he was employed as a draftsman in his present Department. He has worked in various Chevrolet plants during the interim from 1932 to the present time, with the exception of the period from 1937 to 1945 when he was employed by the Hudson Motor Car Company. He was promoted to his present position in February 1953. He is a member of the Engineering Society of Detroit and the American Society of Body Engineers.

• **Leland D. Cobb,** *New Departure Division, Bristol, Connecticut, for a Demountable Seal, No. 2,655,393, issued October 13.* This patent relates to a demountable seal which may easily be snapped into and out of an antifriction bearing to retain lubricant within the bearing and to facilitate cleaning and relubrication.

Mr. Cobb serves as manager of the Research and Development Laboratory at New Departure. He started with the Division in 1928 as a junior engineer and was promoted through the positions of physical test engineer, project engineer on textile applications, executive engineer, assistant to the general manager, and manager of Research and Development to his present position, manager of the Research and Development Laboratory. Mr. Cobb attended Pratt Institute in New York. He is a member of the American Society of Mechanical Engineers, the Society of Automotive Engineers, and serves on a committee of the American Standards Association.

• **Albert J. Kuhn,** *Frigidaire Division, Dayton, Ohio, for an Electrical Apparatus Including Plural Generators and Loads, No. 2,655,602, issued October 13.* This invention relates to a dual generator system in which either one or both generators may be connected to the load. The system requires only one voltage regulator and includes means for automatically disconnecting secondary loads when only one generator operates.

Mr. Kuhn is senior project engineer in the Household Engineering Department at Frigidaire. He earned the B.S.E.E. degree in 1930 from University of Dayton. Mr. Kuhn started with the Division in January 1937 as a junior project engineer. At present, he is concerned with railway air conditioning, Diesel power units, and freight car refrigeration. He has appeared as a speaker on the subject of Diesel power units. Previous to employment with General Motors, Mr. Kuhn was a design engineer at the Leland Electric Company.

A Typical Problem in Automotive Design: Determining Exhaust Valve Cone Angle for a Ball in the Dynaflow Transmission

By CLIFFORD C. WRIGLEY
General Motors
Engineering Staff

How a simple device controls a clutch

An automatic transmission is filled with numerous, hidden engineering problems, the solution of which finally determines the success of the product. Releasing a hydraulically-applied rotating clutch is one such problem. To apply the clutch, the transmission-line pressure is introduced into the clutch housing near the inner diameter of the clutch piston cavity. Cutting off this pressure to the clutch, however, fails to drain the oil because it will not return through the center of a rotating housing. The trapped oil in the rotating housing is subject to the centrifugal pressure of rotation and the clutch tends to apply centrifugally. The release of the clutch can be successfully controlled by a centrifugal ball exhaust valve, wherein the cone angle must be calculated for its optimum value.

THE Buick Dynaflow transmission, in its early design, presented the problem of eliminating the tendency of the clutch to apply centrifugally.

There are four specific conditions under which the Dynaflow direct-drive clutch must be *free* at high rotating speeds. These are:

(a) When driving the car at high speed, the clutch must release cleanly for coasting in neutral.

(b) When being towed in neutral, the clutch must remain released.

w_1 = 0.0294 lb/in.^{3} = density of automatic transmission oil at 250° F

w_2 = 0.281 lb/in.^{3} = density of steel ball

ω *radians/sec* = rotational velocity of clutch housing—(4,500 rpm maximum)

g = 386 in./sec^2 = gravitational acceleration

P_L lb/in.^{2} = line pressure applied to clutch—(90 psi)

R_s = 1.1 in. = radius of feed-line inlet to clutch

R_e = 2.4 in. = radius of centerline of exhaust ball seat

R_b = 0.093 in. = radius of exhaust ball

α = ½ of the included angle of the conical ball seat

Table I—Values used in the determination of the limits of the exhaust valve cone angle.

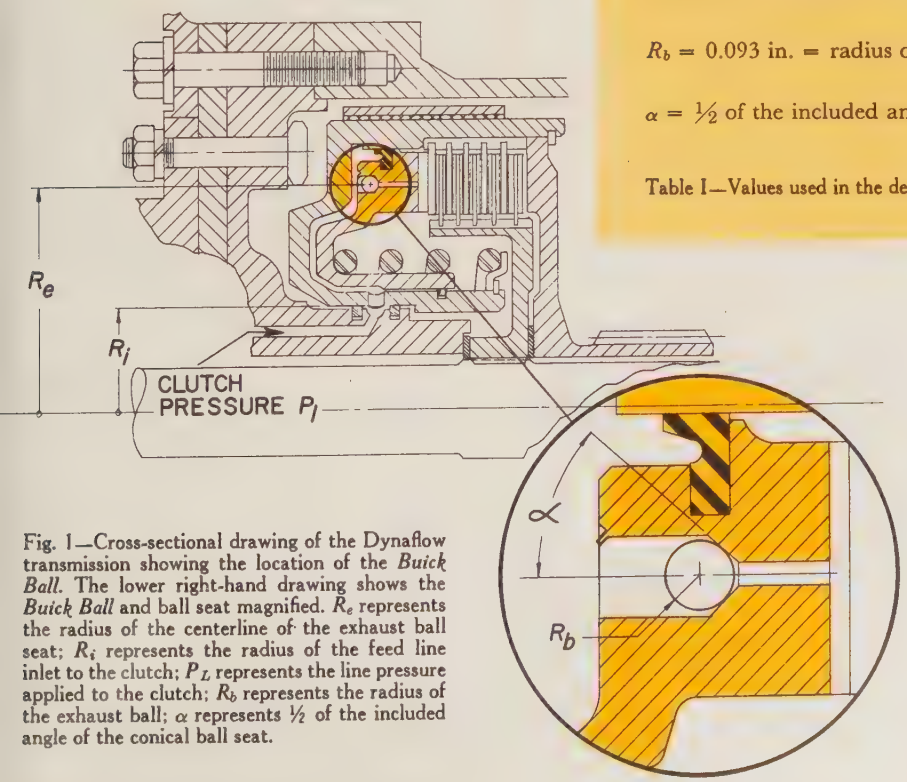


Fig. 1—Cross-sectional drawing of the Dynaflow transmission showing the location of the *Buick Ball*. The lower right-hand drawing shows the *Buick Ball* and ball seat magnified. R_e represents the radius of the centerline of the exhaust ball seat; R_i represents the radius of the feed line inlet to the clutch; P_L represents the line pressure applied to the clutch; R_b represents the radius of the exhaust ball; α represents ½ of the included angle of the conical ball seat.

(c) When the planetary gear train is placed in reverse, the direct-drive clutch housing rotates backward at fairly high speed and the clutch must remain released.

(d) When the car is standing still in neutral and the driver *guns* the engine causing the direct-drive clutch housing to spin backward at fairly high speed, the clutch must remain released.

Failure of the clutch to remain released might result in a burned-out clutch in each of the above instances. Furthermore, there is a serious safety

consideration when the driver guns the engine in neutral if the clutch were to apply itself centrifugally and lurch the car forward.

The obvious solution to this problem, at first thought, was to make the clutch release spring strong enough so that the centrifugal pressure of the trapped oil at the highest operating speed couldn't overcome the spring and apply the clutch. The space required for the installation of such a spring system is one deterring factor, but of greater consequence is the fact that the clutch-application pressure would then have to be substantially increased, with all its disadvantages, to overcome the high force of the release spring.

Some other solution had to be found. A centrifugal ball exhaust valve, the *Buick Ball*, placed near the outer radius of the clutch housing or the piston, and consisting of a conical seat, a coaxial exhaust hole, and a steel ball operating on the seat, provides a more subtle solution (Fig. 1). The centrifugal force of the steel ball tends to remove the ball from the conical seat which, in turn, uncovers the exhaust hole. The oil pressure in the clutch housing tends to force the ball back onto the seat.

The Problem

The problem is to determine an angle for the conical seat so that, when the full application pressure is applied to the clutch, the ball will remain positively seated at the maximum rotating clutch housing speed, and, when the application pressure is cut off leaving only the centrifugal oil pressure in the clutch, the centrifugal force on the steel ball will remove the ball from the seat at any rotating clutch housing speed and exhaust the oil.

Solve for a valve cone angle for a certain set of conditions given in Table I. (*Note:* This will not be a unique solution, but a high and low-angle limit within which the valve will work satisfactorily.)

The transmission-line pressure applied at the inlet of the clutch is 90 psi and, together with the centrifugal pressure, must keep the ball seated up to 4,500 rpm. The ball must unseat itself against the centrifugal oil pressure when the line pressure is cut off. Gravity-force effects on the ball may be neglected.

The solution to the problem will appear in the next issue of the JOURNAL.

The Solution to the Problem: Determine the Most Economical Strip Length for a Bracket

To keep product cost down, the engineer must use raw material in the most efficient and economical manner that is possible. One inch of material wasted in a single operation is magnified by the millions of times that particular operation is performed and, consequently, may run into tons of stock wasted. The solution to the problem presented on page 61 of the November-December 1953 JOURNAL demonstrates how engineers determine, by uncomplicated means, the best blank length for economy and for utility. The length of the blank is *4.017 in.*

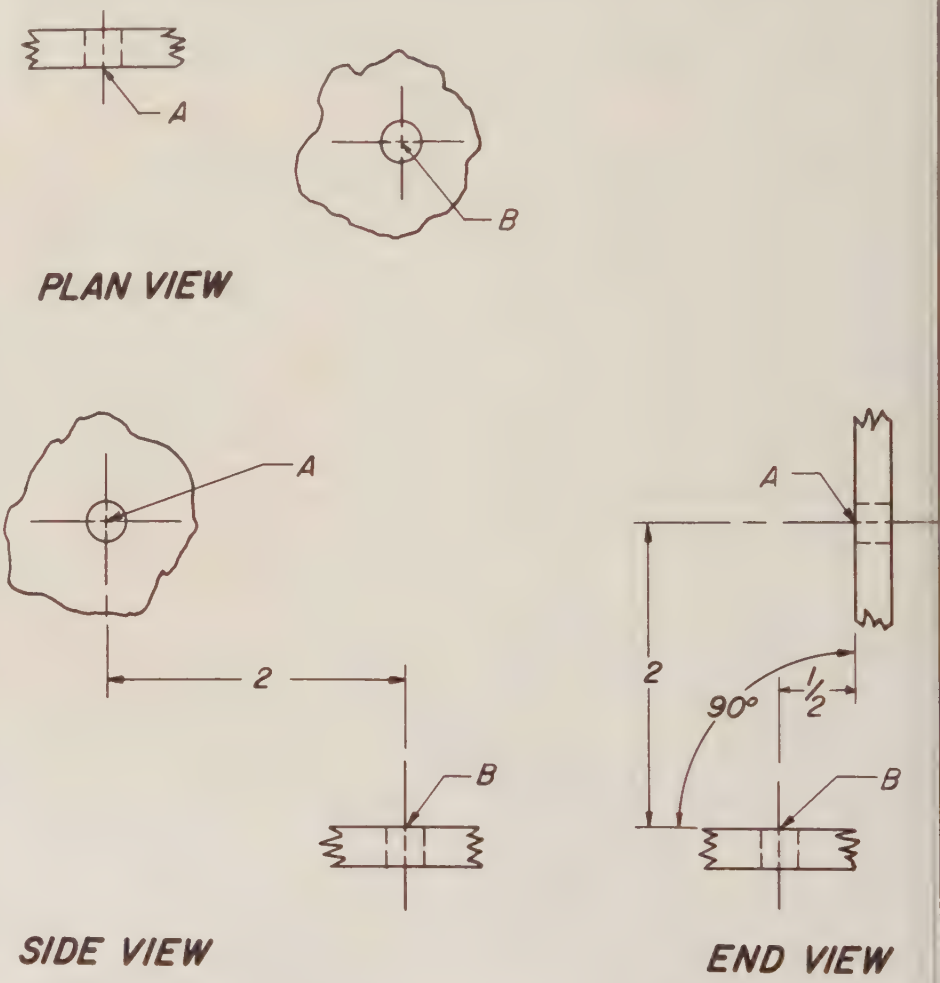


Fig. 1—Principal dimensions between points *A* and *B* which are to be connected by a metal bracket.

DETERMINING the most economical length of a bracket to join the points shown in Fig. 1 is a problem involving relationships between planes and not between points or lines. The problem is simplified by giving an edge view of the planes to be joined, as shown in the end view of Fig. 1.

To join the two planes in the most efficient manner, the following steps may be taken:

(a) In the end view, join the planes by a continuous sheet with a 1/8-in. radius (Fig. 2).

(b) Construct the blank from which the bracket is to be stamped. In this blank, point *A* and point *B*

By CHARLES M. RUBLY
Chevrolet Motor Division

A simplified method to join intersecting planes

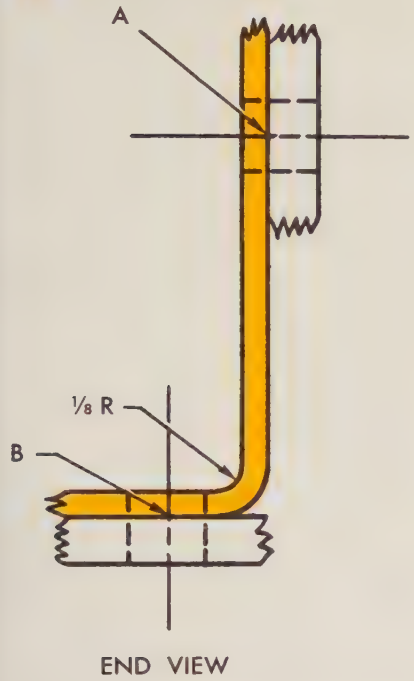


Fig. 2—The end view, showing planes joined by a continuous sheet with a ⅛-in. radius.

will be in the same plane. Therefore, in the drawing, locate these points in the same plane:

- Calculate and lay out the length of metal in the bend using the equation:

$$90° \times \frac{0.0288 \text{ in.}}{10°} = 0.259 \text{ in.}$$

- Lay out the distance from the bend to point *B*.

Find the true distance between *A* and *B* in a true plane in the *side elevation* (Fig. 3).

(a) Construct the blank about the true line *AB* (Fig. 4).

(b) Project the points in the blank back into their respective views and finish the layout drawing of the bracket (Fig. 5).

(c) The length of the blank is *4.017 in.*

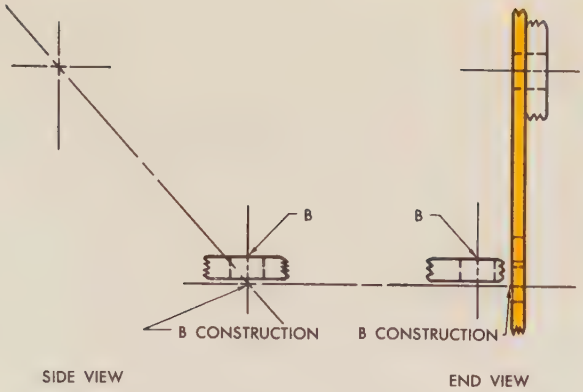


Fig. 3—True distance between *A* and *B* in a true plane is shown in side view.

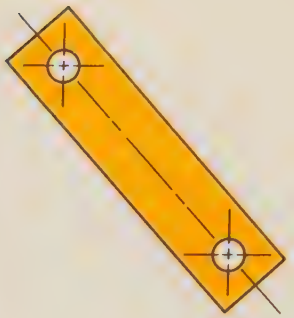


Fig. 4—Blank constructed around the true line *AB*.

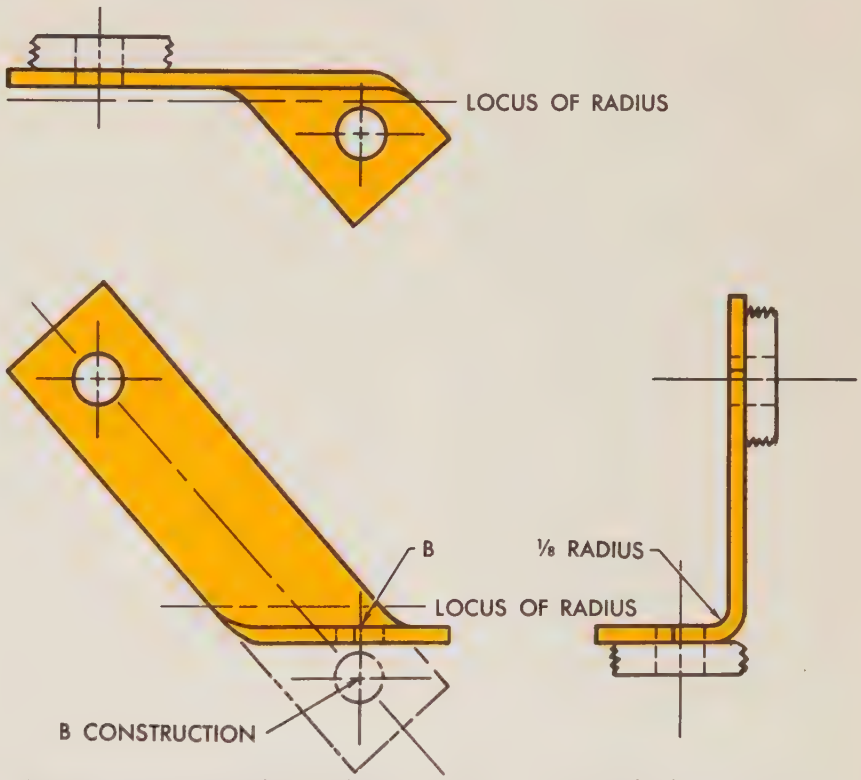


Fig. 5—Points in the blank are shown in their respective views in the completed layout drawing. The length of the blank is *4.017 in.*

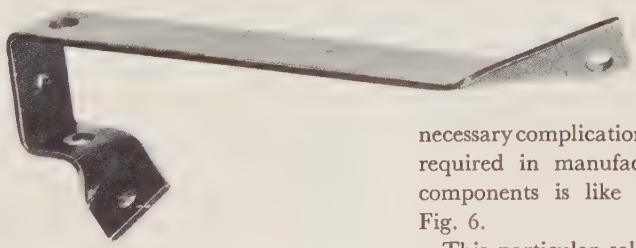
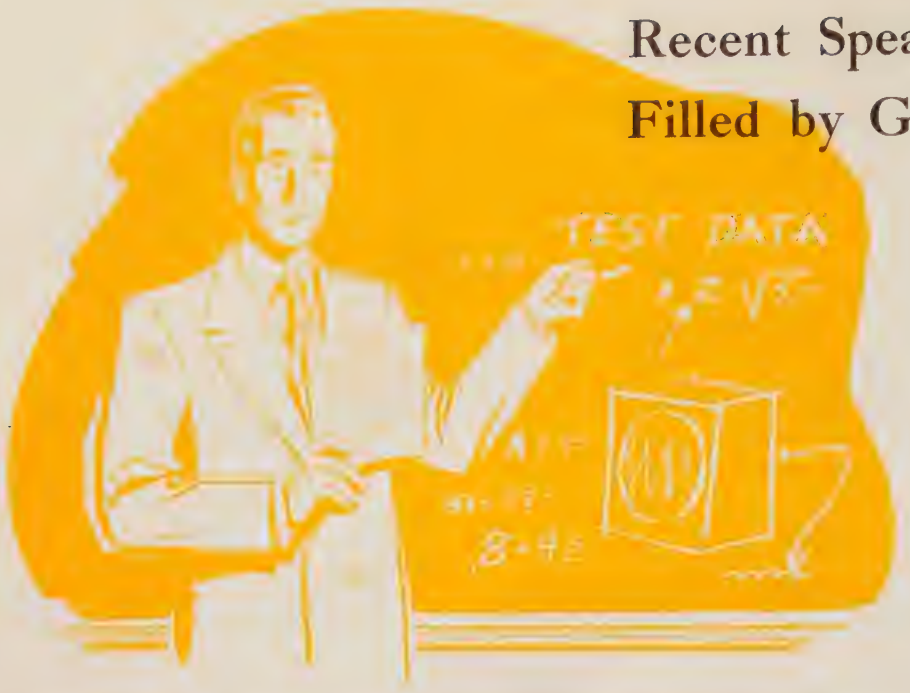


Fig. 6—A typical automotive bracket of the type discussed in this solution.

The statement of the problem is simplified to illustrate the method of finding the best length for the blank without unnecessary complication. The usual bracket required in manufacturing automotive components is like that illustrated in Fig. 6.

This particular solution may be used to join planes intersecting at any angle. Auxiliary views are constructed to attain an edge view of both planes. The defining points are located in a true plane and the blank is constructed in the view adjacent to the edge view of the planes.

Recent Speaking Engagements Filled by GM Engineers



Engineer-lecturers, speaking before technical societies and in engineering classrooms, are but one facet of General Motors continuous program aiming at making available information on GM engineering developments to interested persons outside the Corporation. The appearances mentioned in this report cover the period from October 16 through December 1.

Howard L. Roat, master mechanic at AC Spark Plug Division, Flint, Michigan, spoke to the National Screw Machine Products Association on November 17 in Detroit. He explained the "Principles and Economics of Automation."

Sid S. Hatch, chief test engineer in the Defense Engineering Department of AC Spark Plug, Milwaukee, Wisconsin, spoke to the Marquette University Chapter of Eta Kappa Nu, honorary electrical engineering fraternity, on October 30. His topic was "Engineering in Industry."

Harry W. Lisiak, superintendent of Defense Production at AC Spark Plug, Milwaukee, spoke to a group of high school students in Milwaukee on November 10. He outlined "The Challenge of Youth for Scientific Development for the Next 100 Years."

"The Development of Turbo-Propellers" was the title of the talk given before the Lions Club of Brownsburg, Indiana, on October 28 by **R. E. Reed,** flight test engineer in the Installation Engineering Department of Allison Division.

D. J. Nolan, assistant chief of Installation Engineering at Allison Division, described the "Turbo-Jet and Turbo-Prop Airplanes of the Future" to the Junior Chamber of Commerce of Indianapolis, Indiana, on October 29.

On November 16, during the Aircraft Quality Control Conference held at Dayton, Ohio, **D. F. Flanders,** senior statistician in the Aircraft Engines Operations of Allison, described "Quality Control Charting of Ultrasonic Testing."

The manager of the Transmission Engineering Department at Allison, **R. M. Shaefer,** described "Torque Converters and Hydraulic Transmissions" to the Student Branch of the American Society of Mechanical Engineers at Purdue University on November 17.

This same topic was the subject of the talk given to the Student Branch of the A.S.M.E. at the Georgia Institute of Technology, Atlanta, Georgia, on November 24 by **R. M. Tuck,** development engineer in the Transmission Engineering Department at Allison.

C. W. Hockman, foundry superintendent of Cadillac Motor Car Division's Detroit plant, discussed "Foundry Automation" at the Sixth Annual Purdue University Metal Castings Conference, October 29.

Kenneth A. Meade, director of the Educational Relations Section, Central Office, gave a talk entitled "The Engineer and His Profession" to the Junior Section of the Engineering Society of Detroit on October 28.

Robert Smith, assistant process engineer in the Process Engineering Department, Delco Appliance Division, described "Material Utilization at Delco Appliance"* to the GM Material Utilization Committee in Detroit on October 22.

J. M. Rodgers, general supervisor of the Electrical Process Department of Delco Products Division, outlined the "Opportunities in Electrical Engineering" at the Montgomery County Vocational Guidance Conference held in Dayton, Ohio, on October 26.

C. J. Werner, plants manager in the Manufacturing Department of Delco Products, discussed "How Industrial Management and Education Can Cooperate to Improve Vocational Instruction" before the American Vocational Association on November 24 in Chicago, Illinois.

During the Aircraft Quality Control Conference held at Dayton, Ohio, on November 16 and 17, **Arthur Bender** and **Arnett Hamm,** both quality control engineers at Delco-Remy Division, presented a paper entitled "The Application of Probability Paper to Life (Fatigue) Testing." Earlier in the conference, Mr. Bender gave a paper entitled "You Can Save Time with Probability Paper."

"Fuels and Lubricants for High-Speed Diesel Engine Operations" was the title of the talk given by **Hans M. Gadebusch,** fuels and lubricants engineer at Detroit Diesel Engine Division, to the students of the Standard Oil Company of Indiana Engineering School in Chicago on November 13.

Virgil C. Reddy, development engineer in the Engineering Department of Detroit Diesel, described the "Factors That Affect Diesel Valve Lube Joints" at the November 3 meeting of the Society of Automotive Engineers in Chicago.

Hugh C. Lafferty, senior project engineer in the Mechanical Engineering Section of Electro-Motive Division, discussed the "Design and Maintenance of

*The paper beginning on page 37 is Mr. Smith's adaptation of his talk for the GENERAL MOTORS ENGINEERING JOURNAL.

the GM Locomotive Engine Injection System" before the Southern Railway Club meeting in Atlanta, Georgia, on November 19.

Larry E. Simon, chief metallurgist in the Metallurgy Department of Electro-Motive, spoke at the Magnaflux Railroad Conference held in Chicago on November 19. His topic was "Material Inspection from a Manufacturer's Point of View."

L. W. Schim, engineer-in-charge of the Production Engineering Section, Fisher Body Division, described the "Engineering Processing of the Automobile Body" to the Men's Club of Holy Trinity Church, Detroit on October 27.

On November 17 **William K. Norwick,** executive assistant to the chief engineer, Engineering Division, Fisher Body, presented a talk entitled "Styling and Body Drafting" to the senior class of Highland Park High School, Highland Park, Michigan.

L. H. Grenell, section engineer in the Materials and Process Engineering Department of Frigidaire Division, addressed the American Welding Society on October 20 in Cleveland. His topic was "Silver Brazing Alloys for Corrosion Resistant Joints in Stainless Steel."

Donald J. LaBelle, senior engineer-in-charge of Structural Analysis in the New Developments Department of GMC Truck and Coach Division, on November 2 discussed "Motor Coach Suspensions" before S.A.E. members in Chicago.

Floyd A. Franklin, coach engineer in the Coach Engineering Department of GMC Truck and Coach, described "GMC Air Suspension" to the Lake St. Clair Community Officials on November 4, in Mt. Clemens, Michigan.

C. A. Brown, chairman of the English and Psychology Department of General Motors Institute, spoke at the College English Association Institute held in Corning, New York, on October 16. His topic was "The Teaching of English and Writing of Reports."

F. L. Mackin, chairman of the Machine and Wood Shops Department at G. M. I., discussed "In-Industry Training on Hydraulics" before the National Fluid Power Association at Chicago on October 17.

At the October 22 meeting of the American Mathematical Association held at Columbia University, **Claude E. Stout,** chairman of the Mathematics and Engineering Mechanics Department of G. M. I., presented the talk, "The Aims, Methods, and Problems of Universities in Developing Mathematicians."

Before the Engineers' Club of Flint Junior College on November 18, **Edward A. Reed,** assistant department chairman of the Industrial Engineering Department of G. M. I., outlined the "Field of Tool Engineering." At the same meeting, **Harold M. Dent,** administrative chairman of the Cooperative Engineering Program discussed the "Opportunities in the Field of Engineering."

K. A. Stonex, head of the Technical Data Department, GM Proving Ground, Milford, Michigan, made four speeches during the period covered in this report. On October 22 he explained "Automotive Vehicle Testing at GM Proving Ground" to the vehicle testing class at University of Wisconsin. Later in the same day, he addressed the Wisconsin Section of the American Society of Civil Engineers. The title of this talk was "Automotive Test Track Design." On October 23, again at University of Wisconsin, he described "Automotive Test Track Design" to the highway design class. At the Sixth Annual Illinois Traffic Engineering Conference, held on November 4 at Urbana, Illinois, Mr. Stonex discussed "Trends in Automotive Design Related to Traffic Engineering."

T. J. Carmichael, administrative engineer at the GM Proving Ground, addressed the Third Annual Greater Cincinnati Safety Conference on October 18. The title of his talk was "The Motor Vehicle and Highway Safety."

Paul C. Skeels, head of the Experimental Engineering Department, GM Proving Ground, addressed the Detroit Section of the Instrument Society of America on October 20, describing "Electronic Spark Protractors."

Charles A. Chayne, vice president in charge of Engineering Staff, appeared before the 21st Annual Meeting of the American Association of Motor Vehicle Administrators on October 20 in Richmond, Virginia. His topic was "Automobile Design and Use: A Safety Audit."

Howard K. Gandelot, engineer-in-charge of the Engineering Staff Vehicle Safety Group, located at the GM Technical Center, north of Detroit, spoke to the American Society of Body Engineers on October 28 in Detroit. He discussed the question: "How Safe are Modern Automobiles?"

K. E. Brooker, senior project engineer in the Transmission Development Group, Engineering Staff, GM Technical Center, appeared before engineering students at University of Michigan on November 17, pointing out the "Highlights of American Automatic Transmissions."

W. K. Steinhagen, staff engineer in the Power Development Group, Engineering Staff, GM Technical Center, spoke to engineering students at University of Detroit on October 16. His topic was "A Young Engineer Looks at his First Job."

Raymond J. Lynch, assistant chief engineer in the Product Engineering Department of New Departure Division, spoke to the Business-Industry-Education Committee in Meriden, Connecticut, on October 21. His topic was "The Product Engineer at New Departure."

"Engineering at New Departure" was the talk given to the Business-Industry-Education Committee at Sandusky, Ohio, on October 31 by **Kenneth D. Mackenzie,** manager of engineering and manufacture in the Instrument Bearings Department of New Departure.

Charles R. Gillette, chief chemist in the Product Engineering Department of New Departure, appeared before the New York Chapter of the American Society of Lubrication Engineers in New York City on November 18. The topic of his talk was "Rust Prevention Practices in Manufacturing Operations."

E. M. Estes, body engineer in the Product Engineering Department of Oldsmobile Division, addressed the American Society of Body Engineers in Detroit on October 30. His subject was "Oldsmobile Air Conditioning."

"Oldsmobile's Dual-Purpose Plant Operation" was the title of the talk given by **Marshall D. McCuen,** special assistant to the general superintendent of the Sapphire Jet Plant of Oldsmobile, to the Knights of the Round Table, Lansing, Michigan, on November 2.

J. W. Leggat, assistant chassis engineer in the Engineering Department of Pontiac Motor Division, discussed "Steering and Handling of the Automobile" at Case Institute of Technology, Cleveland, Ohio, on October 21.

Edward F. Weller, assistant department head of the Physics and Instrumentation Department of the Research Laboratories Division, addressed the Instrument Society of America in Detroit on October 20. He described "The Application of the EPUT Meter to

Automotive and Accessory Testing."

The University of Michigan Student Chapter of the American Society of Mechanical Engineers heard **Arthur F. Underwood,** head of the Mechanical Development Department, Research Laboratories, discuss "Bearings" on October 21.

Harry C. Mougey, who retired recently as technical director of the Research Laboratories, presented "Forty Years of Progress in Automotive Lubrication" to the S.A.E. National Fuels and Lubricants Committee in Chicago on November 5. **Harry R. Wolf,** assistant to the technical director of Research Laboratories, presented a discussion of Mr. Mougey's paper at the same meeting.

Darl F. Caris, head of the Automotive Engines Department of Research Laboratories, outlined "Future Trends in Engine Progress" to the Society of Automotive Engineers meeting in Rochester, New York, on November 18.

Calvin H. Hughes, junior research biologist in the Mechanical Development Department of Research Laboratories, appeared before the Mount Olivet Men's Club of Dearborn, Michigan, on November 18. His topic was "The Mechanical Heart and its Clinical Application."

Clovis W. Lincoln, chief engineer in the Engineering Department of Saginaw Steering Gear Division, explained "Power Steering" to the Saginaw Valley Engineers' Club meeting in Bay City, Michigan, on October 22. On November 12 he spoke on this same topic before the Saginaw Valley Chapter of the American Society of Tool Engineers in Saginaw, Michigan.

Ivan S. Kaye, superintendent of the AC Division of McKinnon Industries Limited, St. Catharines, Ontario, spoke to the Canadian Section of the Society of Automotive Engineers in St. Catharines on November 25. His topic was "Making Them Round."

Norman Riley, service engineer in the Sales Department of Rochester Products Division, presented "Valve Timing and Its Relationship to Carburetion" to the Piston Pushers (Student Mechanics) in Rochester, New York, on December 3.

"Improvements of Machine Tools in Today's Shops" was the talk given to the Master Mechanics of America meeting in Buffalo, New York, on December 3 by **James Burnham,** process engineer in the Production Department of Rochester Products.

Contributors to Jan.-Feb. 1954 Issue of

GENERAL MOTORS *Engineering* JOURNAL

W. WALTER BERGER,

contributor of "A Design Study: Planning Maximum Storage and Shipping Ease and Economy into Commercial Vehicle Bodies," serves as senior project engineer in the Engineering Department of the Chevrolet Motor Division's Indianapolis plant. Mr. Berger started his career with General Motors in June 1944 when he was employed as a junior detailer in the Engineering Department of Chevrolet Motor Division, Central Office.

Mr. Berger received his B.S.M.E. degree from General Motors Institute in 1951. During the four year cooperative engineering program at G. M. I. he spent various parts of his work periods at the Flint, Michigan, plant of Chevrolet Motor Division, the GM Proving Ground at Milford, Michigan, and the Chevrolet Engineering Laboratory.

In August 1951 Mr. Berger transferred to the Engineering Department at the Chevrolet-Indianapolis plant engaged in body layout work. He was promoted to senior layout in July 1952 and to his present position, senior project engineer, in February 1953.

In his present capacity, Mr. Berger is concerned with the engineering and designing of Chevrolet single-unit commercial bodies and stake-rack platform bodies. Single-unit commercial Chevrolet bodies consist of ½-ton panel, 1-ton panel, ½-ton suburban carryall, and ½ and 1-ton canopy express truck bodies.

Mr. Berger is a member of Alpha Tau Iota, G. M. I. honorary fraternity, and the Society of Automotive Engineers.

HERBERT H. BLACK,

contributor of "Diesel Engine Improvements through Experimentation with Fuel Injection and Combustion Chamber Relationships," has been a General Motors engineer for more than 20 years. In October 1953 he was appointed assistant chief engineer of Diesel Equipment Division, Grand Rapids, Michigan. In his new position, he is responsible to the chief engineer for the Division's product development work in the Diesel, automotive, and aircraft fields.

Mr. Black was employed by Cadillac Motor Car Division in July 1929 as a die room helper and that fall became a cooperative student at General Motors Institute. Upon his graduation in Automotive Product Engineering in October 1933, he was assigned to the dynamometer room where he spent three years in experimental automotive testing. In 1936 he was transferred to the General Motors Product Study Section, Central Office, as a test engineer, engaged mainly with experimental Diesels.

In January 1938 Mr. Black transferred to the Detroit Diesel Engine Division. One year later he became an experimental engineer working on vehicle, marine, and tank applications of Diesel engines. After becoming a senior experimental engineer in September 1944, he was associated with combustion development projects that included the development of piston and cylinder head inserts, discussed in his current paper. He also has done work on sleeve-valve, port-scavenged, and uni-flow engines.

Mr. Black was transferred to the Diesel Equipment Division in November 1949

as a senior project engineer and assumed charge of the experimental test program on Diesel fuel-injection system development. He continued essentially in this work until his recent promotion. He is a member of the Society of Automotive Engineers and has done General Motors committee work involving Diesel combustion.

ADOLPH F. BRAUN,

contributor of "The Buick Air Power Carburetor," serves as section engineer in the engine division of the Engineering Department, Buick Motor Division. Mr. Braun has done considerable work in the development of compound carburetor systems, and the Buick four-barrel carburetor was one of his principal projects.

Another project, on which he was engaged during the war years, was the design and development of the fuel system for the M-18 gun motor carriage, with special emphasis on extreme hot and cold weather operating characteristics. The final design permitted the vehicle to operate very satisfactorily in a temperature range of −40° F to over +125° F. Two patents relating to carburetors have resulted from his designs.

Mr. Braun began his employment with Buick in July 1928 as a student engineer immediately following his graduation from the University of South Dakota with the B.S.M.E. degree. He had previously obtained a year's experience in power plant design and construction with the South Dakota State Engineering Department. His duties at Buick began as a student engineer spending several months in different divisions of the Engineering Department. Later he transferred to the Carburetor Laboratory as laboratory technician and assisted the carburetor engineer in development and testing.

He has been in the engine division since 1932 where he held the positions of engineer, senior project engineer (1944), and section engineer, which post he was given in 1951.

He is a member of the Society of Automotive Engineers, the American Ordnance Association, and Pi Sigma Pi, a local honorary fraternity.

CHARLES T. CROSS,

contributor of this issue's "Notes About Inventions and Inventors," serves as patent attorney in the Patent Section of the Central Office Staff, Detroit.

While attending law school in Washington, D. C., Mr. Cross began his patent work with General Motors in September 1951 as a patent searcher in the Washington office of the Patent Section. In July 1952 he transferred to the Patent Section, Central Office, Detroit.

Mr. Cross earned the chemical engineering degree in 1950 from University of Cincinnati. He began his law studies at Georgetown Law School, Washington, D. C., and completed his studies at Wayne University Law School, Detroit.

Mr. Cross handles those patent matters principally in the chemical field. As patent attorney, he shares the Patent Section's responsibility of providing necessary and full patent protection for novel apparatuses and processes developed by General Motors employes, of advising engineering organizations on patent matters, and of negotiating royalty arrangements with non-GM companies.

Mr. Cross served in the Army from January 1945 to October 1946, principally as a Signal Corps photographer.

His technical affiliations include membership on the Patents Committee of the American Institute of Chemical Engineers and Alpha Chi Sigma, professional chemical fraternity.

HARVEY L. MANTEY,

contributor of "The Effect of Combustion-Chamber Shape on Smoothness of Power," has served as laboratory supervisor in the Engineering Laboratory of the Cadillac Motor Car Division since August 1950.

Employed by Cadillac Motor Car Division in January 1941 as an assembler, he was chosen by the Division to attend General Motors Institute in September of the same year. His studies were interrupted by military service in the Army from July 1943 to February 1946.

In March 1946 he returned to Cadillac Motor Car Division as a laboratory technician while continuing his studies. Upon receiving the mechanical engineering degree from GM Institute in June 1949, he was promoted to junior engineer and in August 1950 was promoted to his present position.

Mr. Mantey is at present working on the 1954 model Cadillac. He has assisted in developing engines for the '49, '52, and '53 models.

Mr. Mantey is a member of Alpha Tau Iota and the Society of Automotive Engineers. From 1950 to 1952 he was S.A.E. plant representative and was chairman, in 1951, of the Junior Activity Program Committee of the Detroit Section, S.A.E.

HAROLD A. REYNOLDS,

contributor of "Major Cooling Problems Encountered in Today's Automobiles," serves as assistant chief product engineer in the Automotive Section at Harrison Radiator Division, Lockport, New York.

Mr. Reynolds began his General Motors career in 1919 as a senior checker for the Oakland Motor Car Company which had become a Division of GM ten years previously. In 1921 he completed a brief assignment on experimental car design at the Chevrolet Motor Division and during the same year, he transferred to Harrison Radiator. At this Division, he was promoted to assistant commercial engineer in 1926, to experimental engineer in 1928, to sales engineer in 1931, and to assistant chief product engineer in 1938.

Steam-cooled engine design, an artificial marble process, aircraft radiators, oil coolers, and designs of clutches, axles, and chassis for passenger cars and trucks are some of the major projects included in Mr. Reynolds' previous work. At present, he is concerned with passenger car, truck, tractor, and railcar thermostats and radiators. His work in the field of heat transfer media, the subject of his JOURNAL paper, has resulted in four granted patents. He is the author of a published paper on the maintenance of automotive engine cooling systems.

Mr. Reynolds became a member of the Society of Automotive Engineers in

1913 and participates in four of its activities—the Co-ordinating Council, the Transportation and Maintenance Committee, the Cooling System Maintenance Sub-Committee, and the Engine Sub-Committee (chairman).

CHARLES M. RUBLY,

who prepared the solution for the "Typical Problem in Automotive Design," is assistant staff engineer in the Central Office Engineering Department, Chevrolet Motor Division.

Chassis design and design of military heavy tanks have been the two principal activities of his engineering career to date. His automotive experience began in 1930 when he was a draftsman engaged in chassis design. After several years in this work followed by a short period in non-automotive design, he joined Chevrolet in 1939 as a layout man. Until the beginning of World War II, he was concerned with chassis design and experimental model work. In April 1941, he was promoted to designer and six months later was advanced to senior designer.

At the start of the war period, he worked on design of truck vehicles including a special design of a six-wheeled, armoured vehicle. Soon afterward, he was made supervisor of a military project for the fighting compartment of the T-26 heavy tank. In addition to this project, other tank designs were completed under his direction, some of which are still under test by the Army.

In 1946 he was made project engineer and was placed in charge of the ride and handling project for passenger cars. One year later, he directed the design of front suspensions and rear axles and handled additional special assignments. During this period, he assisted Maurice Olley, director of Chevrolet research and development, in the establishment of a drafting department.

In his present position, which he has held since July 1952, he supervises the passenger car design of: chassis, independent front suspensions, frames, power and manual steering, rear axles, rear suspensions, fuel tanks, brakes, wheels, hub caps, and steering wheels. He is a member of the Society of Automotive Engineers.

ROBERT F. SMITH,

contributor of "The Material-Utilization Activity in a Manufacturing Plant," is assistant chief process engineer of the Process Engineering Department at Delco Appliance Division, Rochester, New York. The Process Engineering Department is a process development organization which is engaged in the design and building of a variety of special equipment related to the manufacture of all Delco Appliance products. Cost reduction is the primary objective of this Department.

Typical of the projects on which Mr. Smith has been engaged are (a) expansion of manufacturing facilities for Delco-Heat furnaces and (b) a synchro program for the nation's defense. On the former project, his work included processing and fixture development for domestic furnace production which was increased to three times the former capacity. On the synchro program, he was in charge of the development of certain parts for synchros and servos, and he co-ordinated the subcontracting work. Currently, Mr. Smith's activities are concerned with the processing work necessary for developing facilities to produce actuators for automobile windows and seats.

Mr. Smith joined Delco Appliance in July 1949 following his graduation from Cornell University with the Bachelor of Mechanical Engineering degree. As a part of his initial training program, he was assigned to the Process Engineering Department. He continued in this Department as a process engineer until April 1953, when he was promoted to his present position. He is a veteran of World War II, having served in the United States Air Force from 1943 to 1945.

THOMAS C. VAN DEGRIFT,

contributor of "A Survey of Balancing Machine Developments in the Research Laboratories Division," traces his career as a GM engineer to 1917 when he first joined the Dayton Wright Company as an aeronautical designer.

Since 1926 he has headed the Research Laboratories Division group, now called the Special Problems Department, which has been responsible for the study, development, and production of balancing machines for use on the production line. His direct work on balancing machines covers the full 30-year period which his manuscript surveys and his participation in balancing projects has resulted in 25 patents. In 1940 the National Association of Manufacturers honored his work with the Modern Pioneer Award.

After earlier work as a draftsman, Mr. Van Degrift in 1916 began aircraft work with Orville and Wilbur Wright. In 1917, while the aircraft industry was undergoing changes in ownership and location, he joined the newly-formed Dayton Wright Airplane Company, which in December 1919 was acquired by General Motors. Meanwhile, Mr. Van Degrift had served for a few months in the automotive engineering field with another company but had returned to Dayton Wright in June 1919.

After Dayton Wright became a part of GM, as the GM Research Corporation, Mr. Van Degrift participated in the development of special machinery to be used in producing a copper-cooled engine, which was used by Chevrolet. Then he designed bottling machinery for dispensing ethyl fluid before it was added to gasoline at the tank plant—eliminating the handling of the harmful liquid by chemical workers. In 1925, he moved with his Research Laboratories Department to Detroit. During 1954 he expects to complete the movement of his Department to the GM Technical Center, north of Detroit. Meanwhile, work is continuing on balancing machine developments which already have encompassed production balancing of moving parts ranging in weight from six tons to 1/10 oz.

Mr. Van Degrift is a member of the Society of Automotive Engineers and has served on the S.A.E. Torsional Vibration Committee. He also is a member of the Engineering Society of Detroit.

Contributors' backgrounds vary greatly in detail but each has achieved a technical responsibility in the field in which he writes.

Faith of the Engineer

I AM AN ENGINEER. In my profession I take deep pride, but without vainglory; to it I owe solemn obligations that I am eager to fulfill.

As an Engineer, I will participate in none but honest enterprise. To him that has engaged my services, as employer or client, I will give the utmost of performance and fidelity.

When needed, my skill and knowledge shall be given without reservation for the public good. From special capacity springs the obligation to use it well in the service of humanity; and I accept the challenge that this implies.

Jealous of the high repute of my calling, I will strive to protect the interests and the good name of any engineer that I know to be deserving; but I will not shrink, should duty dictate, from disclosing the truth regarding anyone that, by unscrupulous act, has shown himself unworthy of the profession.

Since the Age of Stone, human progress has been conditioned by the genius of my professional forebears. By them have been rendered usable to mankind Nature's vast resources of material and energy. By them have been vitalized and turned to practical account the principles of science and the revelations of technology. Except for this heritage of accumulated experience, my efforts would be feeble. I dedicate myself to the dissemination of engineering knowledge, and especially to the instruction of younger members of my profession in all its arts and traditions.

To my fellows I pledge, in the same full measure I ask of them, integrity and fair dealing, tolerance and respect, and devotion to the standards and the dignity of our profession; with the consciousness, always, that our special expertness carries with it the obligation to serve humanity with complete sincerity.

Published by permission of Engineers' Council for Professional Development

GENERAL MOTORS

Engineering JOURNAL